

# Pneumonia Image Classification

## Business Understanding:

In this image classification project, I am utilizing neural networks - primarily convolutional neural networks - to create a model that can identify whether or not a patient has pneumonia by analyzing their lung x-rays.

There are two types of pneumonia - bacterial and viral. The image classification system will have to be able to pick out both, while not necessarily knowing which one is which, as the types of pneumonia are not labeled in the dataset.

## Data Understanding:

The dataset is organized into 3 folders (train, test, val) and contains subfolders for each image category (Pneumonia/Normal). There are 5,863 X-Ray images (JPEG) and 2 categories (Pneumonia/Normal).

Chest X-ray images (anterior-posterior) were selected from retrospective cohorts of pediatric patients of one to five years old from Guangzhou Women and Children's Medical Center, Guangzhou. All chest X-ray imaging was performed as part of patients' routine clinical care.

Due to the relatively small amount of validation data (16 images), as well as test data, I will create my own validation data instead of using the provided split.

```

In [2]: import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
import keras
from keras.models import Sequential
from keras.layers import Dense, Conv2D, BatchNormalization, MaxPooling2D, Dropout, Flatten
from sklearn.preprocessing import StandardScaler, LabelBinarizer
import os
os.environ['KMP_DUPLICATE_LIB_OK']='True'
import tensorflow as tf
from keras import models
from keras import layers
import pathlib
import PIL
import seaborn as sns
import time
import scipy
import numpy as np
from PIL import Image
from scipy import ndimage
from sklearn.model_selection import train_test_split, cross_val_score
from keras.preprocessing.image import ImageDataGenerator, array_to_img, img_to_array, load_img
from sklearn.model_selection import train_test_split, cross_val_score
from sklearn.preprocessing import OneHotEncoder
from sklearn.metrics import accuracy_score, confusion_matrix
import matplotlib.pyplot as plt
import matplotlib.image as mpimg
import numpy as np
import seaborn as sns
from tensorflow.keras.models import Sequential
from tensorflow.keras.regularizers import l2
from tensorflow.keras.optimizers import SGD
from tensorflow.keras.wrappers import scikit_learn
from tensorflow.keras.callbacks import EarlyStopping
import shutil
import random
import glob
import os
import sys
import itertools
import warnings
import statistics

```

## Check Data

```
In [3]: train_norm_size = len(os.listdir('re-split_data/train/normal'))
train_pneum_size = len(os.listdir('re-split_data/train/pneumonia'))
test_norm_size = len(os.listdir('re-split_data/test/normal'))
test_pneum_size = len(os.listdir('re-split_data/test/pneumonia'))
valid_norm_size = len(os.listdir('re-split_data/validation/normal'))
valid_pneum_size = len(os.listdir('re-split_data/validation/pneumonia'))

train_size = train_norm_size + train_pneum_size - 1
test_size = test_norm_size + test_pneum_size - 1
validation_size = valid_norm_size + valid_pneum_size

print(f' There are {train_size} images in the training set, {test_size} in
the test set, and {validation_size} in the validation set')

print(f' train norm is {train_norm_size}')
print(f' train pneum is {train_pneum_size}')
print(f' test norm: {test_norm_size}')
print(f' test pneum: {test_pneum_size}')
print(f' valid norm: {valid_norm_size}')
print(f' valid pneum: {valid_pneum_size}')
```

```
There are 3272 images in the training set, 1752 in the test set, and 816 i
n the validation set
train norm is 883
train pneum is 2390
test norm: 473
test pneum: 1280
valid norm: 220
valid pneum: 596
```

## Add Functions

```

In [4]: # Define Result Saving Initial Function
dfcols = ['model_name', 'Train Accuracy', 'Test Accuracy', 'CV1', 'CV2', 'CV3', 'CV4', 'CV5', 'CV_Std', 'CV_avg']
model_summary = pd.DataFrame(columns=dfcols)

def save_result(model_name, Train_Accuracy, Test_Accuracy, cv1, cv2, cv3, cv4, cv5):
    global model_summary
    cv_std = statistics.stdev([cv1, cv2, cv3, cv4, cv5])
    cv_avg = (cv1 + cv2 + cv3 + cv4 + cv5) / 5
    row = [(model_name, Train_Accuracy, Test_Accuracy, cv1, cv2, cv3, cv4, cv5, cv_std, cv_avg)]
    res = pd.DataFrame(columns = dfcols, data = row)
    yeep = [model_summary, res]
    model_summary = pd.concat(yeep)
    model_summary = model_summary.sort_values('CV_avg', ascending = False)
    model_summary = model_summary.drop_duplicates()
    return model_summary.round(3)

```

```

In [5]: # SOURCE: The origin of this confusion matrix code was found on medium, '
# from https://medium.com/@dtuk81/confusion-matrix-visualization-fc31e3f30f
ea
def make_confusion_matrix(cf,
                           group_names=None,
                           categories='auto',
                           count=True,
                           percent=True,
                           cbar=True,
                           xyticks=True,
                           xyplotlabels=True,
                           sum_stats=True,
                           figsize=None,
                           cmap='Blues',
                           title=None):

    # CODE TO GENERATE SUMMARY STATISTICS & TEXT FOR SUMMARY STATS
    if sum_stats:
        #Accuracy is sum of diagonal divided by total observations
        accuracy = np.trace(cf) / float(np.sum(cf))

        #if it is a binary confusion matrix, show some more stats
        if len(cf)==2:
            #Metrics for Binary Confusion Matrices
            a = cf[0,0]
            b = cf[0,1]
            c = cf[1,0]
            d = cf[1,1]
            tn = ((a / (a+b))*100).round(2).astype(str) + '%'
            fp = ((b / (a+b))*100).round(2).astype(str) + '%'
            fn = ((c / (c+d))*100).round(2).astype(str) + '%'
            tp = ((d / (c+d))*100).round(2).astype(str) + '%'
            precision = cf[1,1] / sum(cf[:,1])
            recall = cf[1,1] / sum(cf[1,:])
            f1_score = 2*precision*recall / (precision + recall)
            stats_text = "\n\nAccuracy={: 0.3f}\nPrecision={: 0.3f}\nRecall =
{: 0.3f}\nF1 Score={: 0.3f}".format(
                accuracy, precision, recall, f1_score)
        else:
            stats_text = "\n\nAccuracy={: 0.3f}".format(accuracy)
    else:
        stats_text = ""

    # CODE TO GENERATE TEXT INSIDE EACH SQUARE
    blanks = ['' for i in range(cf.size)]

    if group_names and len(group_names)==cf.size:
        group_labels = ["{}\n".format(value) for value in group_names]
    else:
        group_labels = blanks

    if count:
        group_counts = ["{0:0.0f}\n".format(value) for value in cf.flatten
()]
    else:

```

```

group_counts = blanks

if percent:
    group_percentages = [tn, fp, fn, tp]
    # old = group_percentages = ["{0:.2%}".format(value) for value in c
    f.flatten()/np.sum(cf)]
else:
    group_percentages = blanks

box_labels = [f"{v1}{v2}{v3}".strip() for v1, v2, v3 in zip(group_labels, group_counts, group_percentages)]
box_labels = np.asarray(box_labels).reshape(cf.shape[0], cf.shape[1])

# SET FIGURE PARAMETERS ACCORDING TO OTHER ARGUMENTS
if figsize==None:
    #Get default figure size if not set
    figsize = plt.rcParams.get('figure.figsize')

if xyticks==False:
    #Do not show categories if xyticks is False
    categories=False

# MAKE THE HEATMAP VISUALIZATION
plt.figure(figsize=figsize)
sns.heatmap(cf, annot=box_labels, fmt="", cmap=cmap, cbar=cbar, xticklabels=
categories, yticklabels=categories)

if xyplotlabels:
    plt.ylabel('True Label', weight = 'bold')
    plt.xlabel('Predicted Label' + stats_text, weight = 'bold')
else:
    plt.xlabel(stats_text)

if title:
    plt.title(title, size = 20, weight = 'bold')

```

## Re-Splitting (Hide)

### Check re-aggregated images

Due to the issues with the given train/test split, i re-aggregated the images. From here, I will train/test split the data myself.

```
In [6]: '''
        folder = 're-split_data/NORMAL'
        path = folder

        p = os.listdir(path)
        pf = pd.DataFrame(p)

        norm_tot = len(pf)
        print(f' There are {len(pf[0])} images in the normal folder')
        folder = 're-split_data/PNEUMONIA'
        path = folder
        p = os.listdir(path)
        pf = pd.DataFrame(p)
        pneum_tot = len(pf)
        pneum_weight = len(pf) / 5863
        norm_weight = 1 - pneum_weight
        pf
        print(f' There are {len(pf[0])} images in the pneumonia folder')
        print(f' there are {1576 + len(pf[0])} total images in the dataset')
        print(f' The weight of pneumonia is {round(pneum_weight, 2)}')
        print(f' The weight of normal is {round(norm_weight, 2)}')

        '''
```

```
Out[6]: "\nfolder = 're-split_data/NORMAL'\npath = folder\n\np = os.listdir(path)\n\npf = pd.DataFrame(p)\n\n\nnorm_tot = len(pf)\n\nprint(f' There are {len(pf[0])}\nimages in the normal folder')\n\nfolder = 're-split_data/PNEUMONIA'\n\npath = folder\n\np = os.listdir(path)\n\npf = pd.DataFrame(p)\n\n\npneum_tot = len(pf)\n\npneum_weight = len(pf) / 5863\n\nnorm_weight = 1 - pneum_weight\n\npf\n\nprint(f' There are {len(pf[0])} images in the pneumonia folder')\n\nprint(f' there are {1576 + len(pf[0])} total images in the dataset')\n\nprint(f' The weight of pneumonia is {round(pneum_weight, 2)}')\n\nprint(f' The weight of normal is {round(norm_weight, 2)}')\n\n\n"
```

From here, there is some code which I used to re-split the data.

```
In [7]: # define test and train split percentages
'''
norm_train = norm_tot * .7
norm_test = norm_tot * .3
pneum_train = pneum_tot * .7
pneum_test = pneum_tot * .3
'''

'''
pf = os.listdir('re-split_data/NORMAL')
rand_norm_files = random.sample(pf, int(norm_train))
for file in rand_norm_files:
    shutil.copy('re-split_data/NORMAL/' + file, 're-split_data/train/normal')
'''
```

```
Out[7]: "\npf = os.listdir('re-split_data/NORMAL')\nrand_norm_files = random.sample\n(pf, int(norm_train))\nfor file in rand_norm_files:\n    shutil.copy('re-split_data/NORMAL/' + file, 're-split_data/train/normal')\n"
```

```
In [8]: '''
p1 = os.listdir('re-split_data/train/normal')
p1 = pd.DataFrame(p1)

p2 = os.listdir('re-split_data/NORMAL')
p2 = pd.DataFrame(p2)

tester_files = pd.concat([p1[0], p2[0]]).drop_duplicates(keep=False)
'''
```

```
Out[8]: "\np1 = os.listdir('re-split_data/train/normal')\np1 = pd.DataFrame(p1)\n\np2 = os.listdir('re-split_data/NORMAL')\np2 = pd.DataFrame(p2)\n\ntester_files = pd.concat([p1[0], p2[0]]).drop_duplicates(keep=False)\n"
```

```
In [9]: #for file in tester_files:
        #shutil.copy('re-split_data/NORMAL/' + file, 're-split_data/test/normal')
'''
```



```
In [10]: '''
# The pneumonia files
pf = os.listdir('re-split_data/PNEUMONIA')

rand_Pfiles = random.sample(pf, int(pneum_train))

for file in rand_Pfiles:
    shutil.copy('re-split_data/PNEUMONIA/' + file, 're-split_data/train/pneumonia')

p3 = os.listdir('re-split_data/train/pneumonia')
p3 = pd.DataFrame(p3)

p4 = os.listdir('re-split_data/PNEUMONIA')
p4 = pd.DataFrame(p4)

tester_p = pd.concat([p3[0], p4[0]]).drop_duplicates(keep=False)

for file in tester_p:
    shutil.copy('re-split_data/PNEUMONIA/' + file, 're-split_data/test/pneumonia')
'''
```

```
Out[10]: "\n# The pneumonia files\npf = os.listdir('re-split_data/PNEUMONIA')\n\nrand_Pfiles = random.sample(pf, int(pneum_train))\n\nfor file in rand_Pfiles:\n    n    shutil.copy('re-split_data/PNEUMONIA/' + file, 're-split_data/train/pneumonia')\n\nnp3 = os.listdir('re-split_data/train/pneumonia')\nnp3 = pd.DataFrame(p3)\n\nnp4 = os.listdir('re-split_data/PNEUMONIA')\nnp4 = pd.DataFrame(p4)\n\ntester_p = pd.concat([p3[0], p4[0]]).drop_duplicates(keep=False)\n\nfor file in tester_p:\n    n    shutil.copy('re-split_data/PNEUMONIA/' + file, 're-split_data/test/pneumonia')\n\n"
```

## Validation Files

Make a validation set from the train set

```
In [11]: '''
pf = os.listdir('re-split_data/train/normal')
norm_tot = len(pf)
pf1 = os.listdir('re-split_data/train/pneumonia')
pneum_tot = len(pf1)

print(f' There are {norm_tot} images in the normal training folder and {pneum_tot} in the pneumonia training folder')
'''
```

```
Out[11]: "\n\npf = os.listdir('re-split_data/train/normal')\n\nnorm_tot = len(pf)\n\npf1 = os.listdir('re-split_data/train/pneumonia')\n\npneum_tot = len(pf1)\n\n\nprint(f' There are {norm_tot} images in the normal training folder and {pneum_tot} in the pneumonia training folder')\n"
```

```
In [12]: # I will take 110 images from normal and 298 from pneumonia to create validation set

#rand_sample_norm = random.sample(pf, 110)

#for file in rand_sample_norm:
    #shutil.move('re-split_data/train/normal/' + file, 're-split_data/validation/normal')

#rand_sample_pneum = random.sample(pf1, 298)

#for file in rand_sample_pneum:
    #shutil.move('re-split_data/train/pneumonia/' + file, 're-split_data/validation/pneumonia')

'''
pf2 = os.listdir('re-split_data/validation/normal')
valid_norm_tot = len(pf2)
pf3 = os.listdir('re-split_data/validation/pneumonia')
valid_pneum_tot = len(pf3)

rand_sample_valid_norm = random.sample(pf2, 110)
rand_sample_valid_pneum = random.sample(pf3, 298)

for file in rand_sample_valid_norm:
    shutil.move('re-split_data/validation/normal/' + file, 're-split_data/train/normal')

for file in rand_sample_valid_pneum:
    shutil.move('re-split_data/validation/pneumonia/' + file, 're-split_data/train/pneumonia')

'''
```

```
Out[12]: "\npf2 = os.listdir('re-split_data/validation/normal')\nvalid_norm_tot = len(pf2)\nnpf3 = os.listdir('re-split_data/validation/pneumonia')\nvalid_pneum_tot = len(pf3)\n\nrand_sample_valid_norm = random.sample(pf2, 110)\nrand_sample_valid_pneum = random.sample(pf3, 298)\n\nfor file in rand_sample_valid_norm:\n    shutil.move('re-split_data/validation/normal/' + file, 're-split_data/train/normal')\n\nfor file in rand_sample_valid_pneum:\n    shutil.move('re-split_data/validation/pneumonia/' + file, 're-split_data/train/pneumonia')\n\n\n"
```

## Generate Test and Train Images

```
In [13]: # get all the data in the directory split/test , and reshape them
train_generator = ImageDataGenerator(rescale=1./255).flow_from_directory('re-split_data/train',
                                target_size=(64, 64), batch_size = train_size)

test_generator = ImageDataGenerator(rescale=1./255).flow_from_directory('re-split_data/test',
                                target_size=(64, 64), batch_size = test_size, shuffle= False)

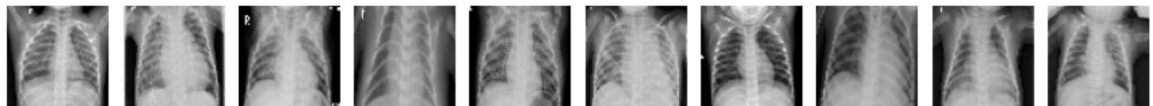
valid_generator = ImageDataGenerator(rescale=1./255).flow_from_directory('re-split_data/validation',
                                target_size=(64, 64), batch_size = validation_size)
```

Found 3272 images belonging to 2 classes.  
Found 1752 images belonging to 2 classes.  
Found 816 images belonging to 2 classes.

```
In [14]: # create the data sets
train_images, train_labels = next(train_generator)
test_images, test_labels = next(test_generator)
valid_images, valid_labels = next(valid_generator)
```

```
In [15]: def show_images(images):
    fig, axes = plt.subplots(1, 10, figsize=(12,12))
    axes = axes.flatten()
    for img, ax in zip(images, axes):
        ax.imshow(img)
        ax.axis('off')
    plt.tight_layout()
    plt.show()
```

```
In [16]: show_images(train_images)
```



```
In [17]: train_img = train_images.reshape(train_images.shape[0], -1)
test_img = test_images.reshape(test_images.shape[0], -1)
valid_img = valid_images.reshape(valid_images.shape[0], -1)

print(train_img.shape)
print(test_img.shape)
print(valid_img.shape)
```

(3272, 12288)  
(1752, 12288)  
(816, 12288)

```
In [18]: train_y = np.reshape(train_labels[:,0], (train_size,1))
test_y = np.reshape(test_labels[:,0], (test_size,1))
valid_y = np.reshape(valid_labels[:,0], (validation_size,1))

print(train_y.shape)
print(test_y.shape)
print(valid_y.shape)

(3272, 1)
(1752, 1)
(816, 1)
```

## Baseline Model

```
In [19]: # Build a baseline fully connected model
model = models.Sequential()
model.add(layers.Dense(20, activation='relu', input_shape=(12288,))) # 2 hidden layers
model.add(layers.Dense(7, activation='relu'))
model.add(layers.Dense(5, activation='relu'))
model.add(layers.Dense(1, activation='sigmoid'))
```

```
In [20]: model.compile(optimizer='sgd',
                        loss='binary_crossentropy',
                        metrics=['accuracy'])

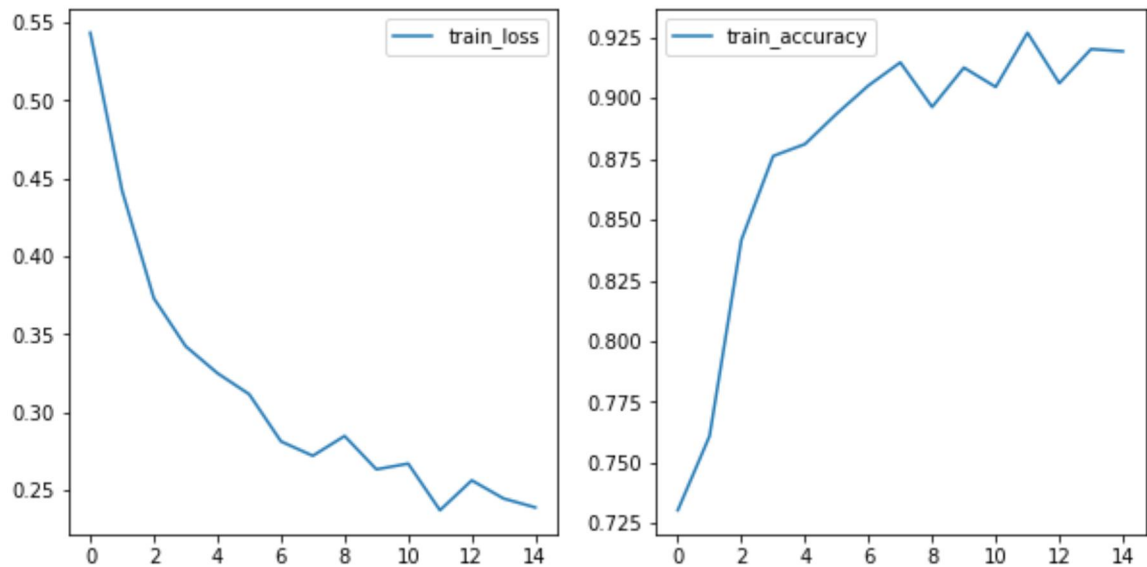
baseline = model.fit(train_img, train_y, epochs=15, batch_size=32)

train_loss = baseline.history['loss']
train_acc = baseline.history['accuracy']

fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(10, 5))
sns.lineplot(x=baseline.epoch, y=train_loss, ax=ax1, label='train_loss')
sns.lineplot(x=baseline.epoch, y=train_acc, ax=ax2, label='train_accuracy')
```

```
Epoch 1/15
103/103 [=====] - 5s 48ms/step - loss: 0.5433 - ac
curacy: 0.7304
Epoch 2/15
103/103 [=====] - 5s 51ms/step - loss: 0.4422 - ac
curacy: 0.7610
Epoch 3/15
103/103 [=====] - 5s 46ms/step - loss: 0.3731 - ac
curacy: 0.8417
Epoch 4/15
103/103 [=====] - 5s 44ms/step - loss: 0.3424 - ac
curacy: 0.8762
Epoch 5/15
103/103 [=====] - 5s 46ms/step - loss: 0.3251 - ac
curacy: 0.8811
Epoch 6/15
103/103 [=====] - 5s 48ms/step - loss: 0.3116 - ac
curacy: 0.8936
Epoch 7/15
103/103 [=====] - 5s 44ms/step - loss: 0.2814 - ac
curacy: 0.9053
Epoch 8/15
103/103 [=====] - 5s 47ms/step - loss: 0.2722 - ac
curacy: 0.9147
Epoch 9/15
103/103 [=====] - 5s 46ms/step - loss: 0.2848 - ac
curacy: 0.8964
Epoch 10/15
103/103 [=====] - 5s 49ms/step - loss: 0.2635 - ac
curacy: 0.9126
Epoch 11/15
103/103 [=====] - 5s 48ms/step - loss: 0.2671 - ac
curacy: 0.9046
Epoch 12/15
103/103 [=====] - 5s 45ms/step - loss: 0.2373 - ac
curacy: 0.9270
Epoch 13/15
103/103 [=====] - 5s 46ms/step - loss: 0.2564 - ac
curacy: 0.9062
Epoch 14/15
103/103 [=====] - 5s 46ms/step - loss: 0.2448 - ac
curacy: 0.9202
Epoch 15/15
103/103 [=====] - 5s 50ms/step - loss: 0.2390 - ac
curacy: 0.9193
```

Out[20]: <AxesSubplot: >



## SkLearn Version for Cross-Validation

```
In [21]: # Build function that builds the model so we can evaluate in sklearn
def build_model():
    model.add(layers.Dense(20, activation='relu', input_shape=(12288,))) #
    2 hidden layers
    model.add(layers.Dense(7, activation='relu'))
    model.add(layers.Dense(5, activation='relu'))
    model.add(layers.Dense(1, activation='sigmoid'))

    model.compile(optimizer='sgd',
                  loss='binary_crossentropy',
                  metrics=['accuracy'])

    return model
```

```
In [22]: keras_model = sklearn.KerasClassifier(build_model,
                                                epochs=15,
                                                batch_size=32,
                                                verbose=2)
```

## Cross-Validation

```
In [23]: # Now that it is a keras model, you can cross-validate it  
cvs = cross_val_score(keras_model, train_img, train_y, cv=5)
```



Epoch 1/15  
82/82 - 4s - loss: 0.6216 - accuracy: 0.7287  
Epoch 2/15  
82/82 - 3s - loss: 0.5435 - accuracy: 0.7302  
Epoch 3/15  
82/82 - 3s - loss: 0.4948 - accuracy: 0.7302  
Epoch 4/15  
82/82 - 3s - loss: 0.4498 - accuracy: 0.7302  
Epoch 5/15  
82/82 - 4s - loss: 0.4058 - accuracy: 0.7302  
Epoch 6/15  
82/82 - 3s - loss: 0.3614 - accuracy: 0.8540  
Epoch 7/15  
82/82 - 3s - loss: 0.3198 - accuracy: 0.9350  
Epoch 8/15  
82/82 - 3s - loss: 0.2852 - accuracy: 0.9354  
Epoch 9/15  
82/82 - 3s - loss: 0.2690 - accuracy: 0.9251  
Epoch 10/15  
82/82 - 3s - loss: 0.2546 - accuracy: 0.9217  
Epoch 11/15  
82/82 - 3s - loss: 0.2298 - accuracy: 0.9331  
Epoch 12/15  
82/82 - 3s - loss: 0.2185 - accuracy: 0.9316  
Epoch 13/15  
82/82 - 3s - loss: 0.2262 - accuracy: 0.9247  
Epoch 14/15  
82/82 - 3s - loss: 0.2229 - accuracy: 0.9209  
Epoch 15/15  
82/82 - 3s - loss: 0.2047 - accuracy: 0.9320  
21/21 - 1s - loss: 0.2280 - accuracy: 0.9252  
Epoch 1/15  
82/82 - 4s - loss: 0.6619 - accuracy: 0.7279  
Epoch 2/15  
82/82 - 4s - loss: 0.6078 - accuracy: 0.7279  
Epoch 3/15  
82/82 - 3s - loss: 0.5923 - accuracy: 0.7279  
Epoch 4/15  
82/82 - 4s - loss: 0.5875 - accuracy: 0.7279  
Epoch 5/15  
82/82 - 3s - loss: 0.5861 - accuracy: 0.7279  
Epoch 6/15  
82/82 - 3s - loss: 0.5857 - accuracy: 0.7279  
Epoch 7/15  
82/82 - 3s - loss: 0.5855 - accuracy: 0.7279  
Epoch 8/15  
82/82 - 4s - loss: 0.5854 - accuracy: 0.7279  
Epoch 9/15  
82/82 - 3s - loss: 0.5855 - accuracy: 0.7279  
Epoch 10/15  
82/82 - 4s - loss: 0.5854 - accuracy: 0.7279  
Epoch 11/15  
82/82 - 3s - loss: 0.5854 - accuracy: 0.7279  
Epoch 12/15  
82/82 - 4s - loss: 0.5854 - accuracy: 0.7279  
Epoch 13/15

82/82 - 3s - loss: 0.5854 - accuracy: 0.7279  
Epoch 14/15  
82/82 - 4s - loss: 0.5854 - accuracy: 0.7279  
Epoch 15/15  
82/82 - 4s - loss: 0.5854 - accuracy: 0.7279  
21/21 - 1s - loss: 0.5731 - accuracy: 0.7405  
Epoch 1/15  
82/82 - 4s - loss: 0.6681 - accuracy: 0.7242  
Epoch 2/15  
82/82 - 3s - loss: 0.6342 - accuracy: 0.7311  
Epoch 3/15  
82/82 - 3s - loss: 0.6136 - accuracy: 0.7311  
Epoch 4/15  
82/82 - 4s - loss: 0.6009 - accuracy: 0.7311  
Epoch 5/15  
82/82 - 3s - loss: 0.5933 - accuracy: 0.7311  
Epoch 6/15  
82/82 - 4s - loss: 0.5887 - accuracy: 0.7311  
Epoch 7/15  
82/82 - 4s - loss: 0.5860 - accuracy: 0.7311  
Epoch 8/15  
82/82 - 4s - loss: 0.5843 - accuracy: 0.7311  
Epoch 9/15  
82/82 - 3s - loss: 0.5834 - accuracy: 0.7311  
Epoch 10/15  
82/82 - 4s - loss: 0.5829 - accuracy: 0.7311  
Epoch 11/15  
82/82 - 3s - loss: 0.5826 - accuracy: 0.7311  
Epoch 12/15  
82/82 - 4s - loss: 0.5824 - accuracy: 0.7311  
Epoch 13/15  
82/82 - 4s - loss: 0.5823 - accuracy: 0.7311  
Epoch 14/15  
82/82 - 3s - loss: 0.5823 - accuracy: 0.7311  
Epoch 15/15  
82/82 - 4s - loss: 0.5822 - accuracy: 0.7311  
21/21 - 1s - loss: 0.5854 - accuracy: 0.7278  
Epoch 1/15  
82/82 - 4s - loss: 0.6432 - accuracy: 0.7357  
Epoch 2/15  
82/82 - 4s - loss: 0.5978 - accuracy: 0.7357  
Epoch 3/15  
82/82 - 3s - loss: 0.5833 - accuracy: 0.7357  
Epoch 4/15  
82/82 - 3s - loss: 0.5793 - accuracy: 0.7357  
Epoch 5/15  
82/82 - 4s - loss: 0.5780 - accuracy: 0.7357  
Epoch 6/15  
82/82 - 3s - loss: 0.5777 - accuracy: 0.7357  
Epoch 7/15  
82/82 - 3s - loss: 0.5777 - accuracy: 0.7357  
Epoch 8/15  
82/82 - 3s - loss: 0.5776 - accuracy: 0.7357  
Epoch 9/15  
82/82 - 3s - loss: 0.5777 - accuracy: 0.7357  
Epoch 10/15

```

82/82 - 3s - loss: 0.5776 - accuracy: 0.7357
Epoch 11/15
82/82 - 3s - loss: 0.5776 - accuracy: 0.7357
Epoch 12/15
82/82 - 3s - loss: 0.5777 - accuracy: 0.7357
Epoch 13/15
82/82 - 3s - loss: 0.5776 - accuracy: 0.7357
Epoch 14/15
82/82 - 3s - loss: 0.5777 - accuracy: 0.7357
Epoch 15/15
82/82 - 4s - loss: 0.5777 - accuracy: 0.7357
21/21 - 1s - loss: 0.6042 - accuracy: 0.7095
Epoch 1/15
82/82 - 4s - loss: 0.6288 - accuracy: 0.7273
Epoch 2/15
82/82 - 4s - loss: 0.5908 - accuracy: 0.7273
Epoch 3/15
82/82 - 3s - loss: 0.5865 - accuracy: 0.7273
Epoch 4/15
82/82 - 4s - loss: 0.5861 - accuracy: 0.7273
Epoch 5/15
82/82 - 4s - loss: 0.5861 - accuracy: 0.7273
Epoch 6/15
82/82 - 4s - loss: 0.5862 - accuracy: 0.7273
Epoch 7/15
82/82 - 3s - loss: 0.5863 - accuracy: 0.7273
Epoch 8/15
82/82 - 4s - loss: 0.5862 - accuracy: 0.7273
Epoch 9/15
82/82 - 3s - loss: 0.5862 - accuracy: 0.7273
Epoch 10/15
82/82 - 4s - loss: 0.5862 - accuracy: 0.7273
Epoch 11/15
82/82 - 3s - loss: 0.5862 - accuracy: 0.7273
Epoch 12/15
82/82 - 4s - loss: 0.5861 - accuracy: 0.7273
Epoch 13/15
82/82 - 3s - loss: 0.5862 - accuracy: 0.7273
Epoch 14/15
82/82 - 4s - loss: 0.5862 - accuracy: 0.7273
Epoch 15/15
82/82 - 3s - loss: 0.5862 - accuracy: 0.7273
21/21 - 1s - loss: 0.5701 - accuracy: 0.7431

```

## Results

```
In [24]: results_train = model.evaluate(train_img, train_y)
```

```

103/103 [=====] - 5s 47ms/step - loss: 0.5828 - ac
curacy: 0.7304

```

```
In [25]: results_test = model.evaluate(test_img, test_y)
```

```
55/55 [=====] - 2s 41ms/step - loss: 0.5832 - accuracy: 0.7300
```

```
In [26]: save_result('Initial Model', results_train[1], results_test[1], cvs[0], cvs[1], cvs[2], cvs[3], cvs[4])
```

Out[26]:

	model_name	Train Accuracy	Test Accuracy	CV1	CV2	CV3	CV4	CV5	CV_Std	CV_avg
0	Initial Model	0.73	0.73	0.925	0.74	0.728	0.709	0.743	0.088	0.769

```
In [27]: predictions = model.predict(x = test_img, verbose=0)
```

```
In [28]: pred_check = np.round(predictions)
```

```
In [29]: pred_check = pred_check[:]
pred_check = pred_check.flatten()
pred_check
```

Out[29]: array([0., 0., 0., ..., 0., 0., 0.], dtype=float32)

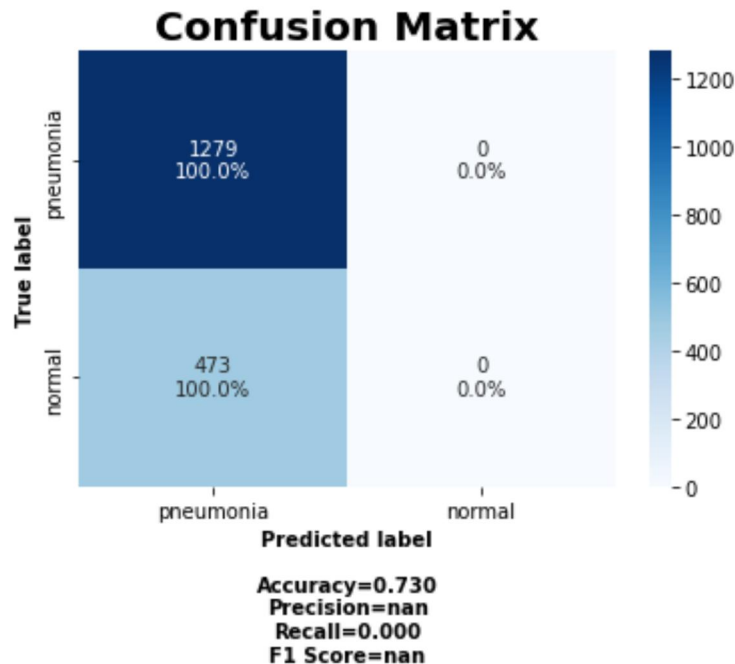
```
In [30]: test_check = test_labels[:,0]
test_check
```

Out[30]: array([1., 1., 1., ..., 0., 0., 0.], dtype=float32)

```
In [31]: cm = confusion_matrix(y_true=test_check, y_pred=pred_check)
```

```
In [32]: cm_plot_labels = ['pneumonia', 'normal']
make_confusion_matrix(cm, categories = cm_plot_labels, title='Confusion Matrix')
```

C:\Users\tmcro\AppData\Local\Temp\ipykernel\_35652\728492238.py:32: RuntimeWarning: invalid value encountered in longlong\_scalars  
precision = cf[1,1] / sum(cf[:,1])



## Convolutional Neural Network (CNN)

```
In [33]: model = models.Sequential()

model.add(layers.Conv2D(32, (3, 3), activation='relu',
                        input_shape=(64, 64, 3)))
model.add(layers.MaxPooling2D((2, 2)))

model.add(layers.Conv2D(32, (4, 4), activation='relu'))
model.add(layers.MaxPooling2D((2, 2)))

model.add(layers.Conv2D(64, (3, 3), activation='relu'))
model.add(layers.MaxPooling2D((2, 2)))

model.add(layers.Flatten())
model.add(layers.Dense(64, activation='relu'))
model.add(layers.Dense(1, activation='sigmoid'))
```

In [34]: `model.summary()`

Model: "sequential\_1"

Layer (type)	Output Shape	Param #
=====		
conv2d (Conv2D)	(None, 62, 62, 32)	896
max_pooling2d (MaxPooling2D)	(None, 31, 31, 32)	0
conv2d_1 (Conv2D)	(None, 28, 28, 32)	16416
max_pooling2d_1 (MaxPooling2D)	(None, 14, 14, 32)	0
conv2d_2 (Conv2D)	(None, 12, 12, 64)	18496
max_pooling2d_2 (MaxPooling2D)	(None, 6, 6, 64)	0
flatten (Flatten)	(None, 2304)	0
dense_24 (Dense)	(None, 64)	147520
dense_25 (Dense)	(None, 1)	65
=====		
Total params: 183,393		
Trainable params: 183,393		
Non-trainable params: 0		

In [35]: `model.compile(loss='binary_crossentropy',  
optimizer="sgd",  
metrics=['accuracy'])`

## Train Initial Simple CNN

[illegible]

Epoch 1/25  
103/103 [=====] - 7s 67ms/step - loss: 0.5938 - accuracy: 0.7210 - val\_loss: 0.5713 - val\_accuracy: 0.7304  
Epoch 2/25  
103/103 [=====] - 6s 62ms/step - loss: 0.5529 - accuracy: 0.7304 - val\_loss: 0.5191 - val\_accuracy: 0.7304  
Epoch 3/25  
103/103 [=====] - 6s 60ms/step - loss: 0.4966 - accuracy: 0.7491 - val\_loss: 0.4855 - val\_accuracy: 0.8897  
Epoch 4/25  
103/103 [=====] - 7s 66ms/step - loss: 0.4160 - accuracy: 0.8114 - val\_loss: 0.3164 - val\_accuracy: 0.8787  
Epoch 5/25  
103/103 [=====] - 6s 62ms/step - loss: 0.3189 - accuracy: 0.8661 - val\_loss: 0.2415 - val\_accuracy: 0.8995  
Epoch 6/25  
103/103 [=====] - 6s 60ms/step - loss: 0.2683 - accuracy: 0.8869 - val\_loss: 0.4556 - val\_accuracy: 0.7819  
Epoch 7/25  
103/103 [=====] - 6s 62ms/step - loss: 0.2249 - accuracy: 0.9089 - val\_loss: 0.1927 - val\_accuracy: 0.9216  
Epoch 8/25  
103/103 [=====] - 7s 68ms/step - loss: 0.2196 - accuracy: 0.9095 - val\_loss: 0.3193 - val\_accuracy: 0.8640  
Epoch 9/25  
103/103 [=====] - 6s 62ms/step - loss: 0.2070 - accuracy: 0.9175 - val\_loss: 0.1624 - val\_accuracy: 0.9338  
Epoch 10/25  
103/103 [=====] - 7s 64ms/step - loss: 0.1981 - accuracy: 0.9230 - val\_loss: 0.1653 - val\_accuracy: 0.9375  
Epoch 11/25  
103/103 [=====] - 7s 64ms/step - loss: 0.1899 - accuracy: 0.9233 - val\_loss: 0.1614 - val\_accuracy: 0.9387  
Epoch 12/25  
103/103 [=====] - 6s 58ms/step - loss: 0.1812 - accuracy: 0.9303 - val\_loss: 0.1517 - val\_accuracy: 0.9449  
Epoch 13/25  
103/103 [=====] - 7s 65ms/step - loss: 0.1762 - accuracy: 0.9318 - val\_loss: 0.1919 - val\_accuracy: 0.9154  
Epoch 14/25  
103/103 [=====] - 7s 64ms/step - loss: 0.1782 - accuracy: 0.9285 - val\_loss: 0.2628 - val\_accuracy: 0.8909  
Epoch 15/25  
103/103 [=====] - 6s 63ms/step - loss: 0.1730 - accuracy: 0.9322 - val\_loss: 0.1546 - val\_accuracy: 0.9510  
Epoch 16/25  
103/103 [=====] - 6s 61ms/step - loss: 0.1693 - accuracy: 0.9352 - val\_loss: 0.1487 - val\_accuracy: 0.9534  
Epoch 17/25  
103/103 [=====] - 6s 63ms/step - loss: 0.1616 - accuracy: 0.9358 - val\_loss: 0.1341 - val\_accuracy: 0.9608  
Epoch 18/25  
103/103 [=====] - 7s 64ms/step - loss: 0.1622 - accuracy: 0.9370 - val\_loss: 0.1365 - val\_accuracy: 0.9583  
Epoch 19/25  
103/103 [=====] - 6s 61ms/step - loss: 0.1557 - ac



```

curacy: 0.9425 - val_loss: 0.3232 - val_accuracy: 0.8542
Epoch 20/25
103/103 [=====] - 7s 64ms/step - loss: 0.1552 - ac
curacy: 0.9438 - val_loss: 0.1378 - val_accuracy: 0.9522
Epoch 21/25
103/103 [=====] - 6s 61ms/step - loss: 0.1421 - ac
curacy: 0.9468 - val_loss: 0.1248 - val_accuracy: 0.9608
Epoch 22/25
103/103 [=====] - 6s 60ms/step - loss: 0.1405 - ac
curacy: 0.9502 - val_loss: 0.2120 - val_accuracy: 0.9093
Epoch 23/25
103/103 [=====] - 7s 64ms/step - loss: 0.1519 - ac
curacy: 0.9438 - val_loss: 0.2384 - val_accuracy: 0.9056
Epoch 24/25
103/103 [=====] - 6s 61ms/step - loss: 0.1435 - ac
curacy: 0.9447 - val_loss: 0.1409 - val_accuracy: 0.9534
Epoch 25/25
103/103 [=====] - 6s 62ms/step - loss: 0.1330 - ac
curacy: 0.9496 - val_loss: 0.1171 - val_accuracy: 0.9657

```

```
In [37]: results_train = model.evaluate(train_images, train_y)
```

```

103/103 [=====] - 2s 17ms/step - loss: 0.1253 - ac
curacy: 0.9529

```

```
In [38]: results_test = model.evaluate(test_images, test_y)
```

```

55/55 [=====] - 1s 23ms/step - loss: 0.1745 - accu
racy: 0.9332

```

## Prediction for Confusion Matrix

```
In [39]: predictions = model.predict(x = test_images, steps = 10, verbose=0)
```

```
In [40]: pred_check = np.round(predictions)
```

```
In [41]: pred_check = pred_check[:]
pred_check = pred_check.flatten()
pred_check
```

```
Out[41]: array([0., 1., 1., ..., 0., 0., 0.], dtype=float32)
```

```
In [42]: test_check = test_labels[:,0]
test_check
```

```
Out[42]: array([1., 1., 1., ..., 0., 0., 0.], dtype=float32)
```

```
In [43]: cm = confusion_matrix(y_true=test_check, y_pred=pred_check)
```

In [44]: cm

Out[44]: array([[1231, 48],  
[ 69, 404]], dtype=int64)

```
In [45]: def plot_confusion_matrix(cm, classes,  
                                   normalize=False,  
                                   title='Confusion matrix',  
                                   cmap=plt.cm.Blues):  
  
    """  
    This function prints and plots the confusion matrix.  
    Normalization can be applied by setting `normalize=True`.  
    """  
  
    plt.imshow(cm, interpolation='nearest', cmap=cmap)  
    plt.title(title)  
    plt.colorbar()  
    tick_marks = np.arange(len(classes))  
    plt.xticks(tick_marks, classes, rotation=45)  
    plt.yticks(tick_marks, classes)  
  
    if normalize:  
        cm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]  
        print("Normalized confusion matrix")  
    else:  
        print('Confusion matrix, without normalization')  
  
    print(cm)  
  
    thresh = cm.max() / 2.  
    for i, j in itertools.product(range(cm.shape[0]), range(cm.shape[1])):  
        plt.text(j, i, cm[i, j],  
                 horizontalalignment="center",  
                 color="white" if cm[i, j] > thresh else "black")
```

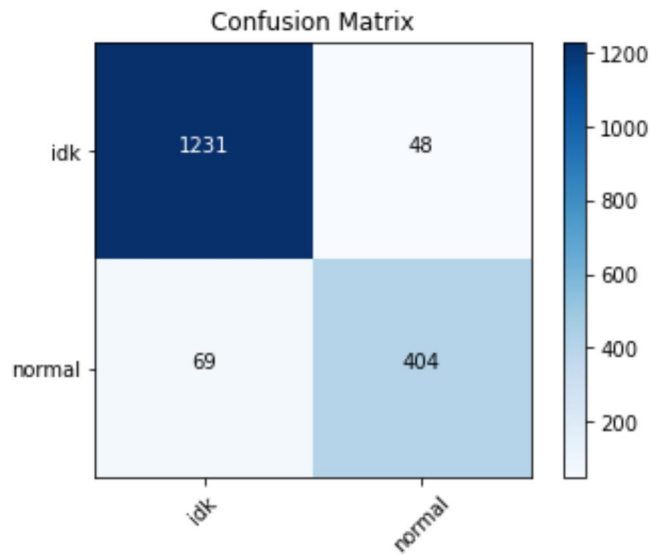
In [46]: {'normal': 0, 'pneumonia': 1}

Out[46]: {'normal': 0, 'pneumonia': 1}

```
In [47]: cm_plot_labels = ['idk', 'normal']  
plot_confusion_matrix(cm=cm, classes=cm_plot_labels, title='Confusion Matrix')
```

Confusion matrix, without normalization

```
[[1231  48]  
 [ 69 404]]
```

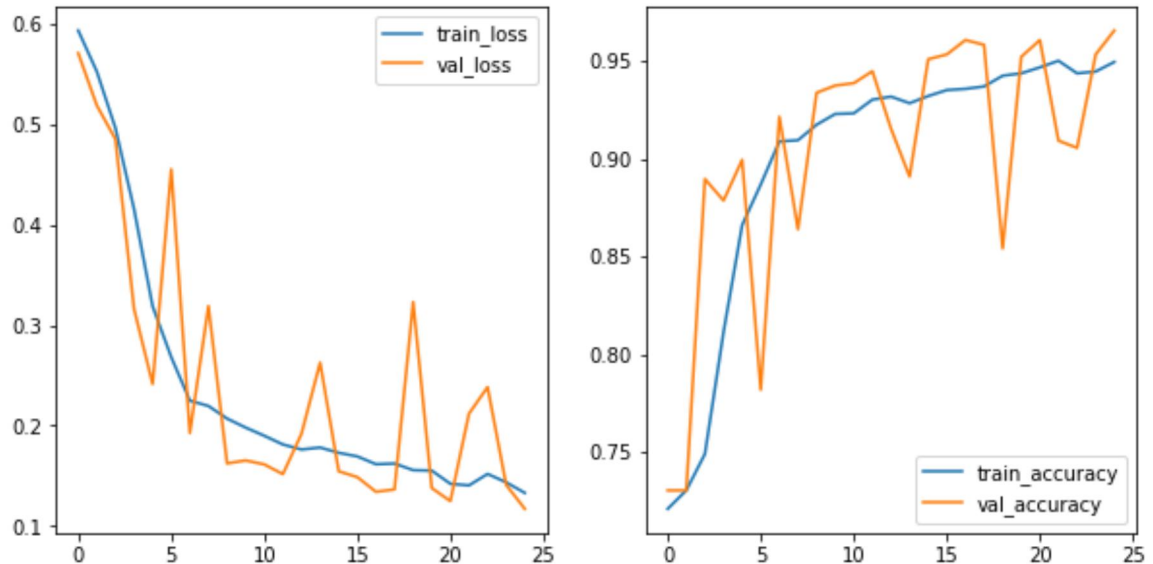


## CNN #1 Results

```
In [48]: train_loss = cnn_1.history['loss']
train_acc = cnn_1.history['accuracy']
val_loss = cnn_1.history['val_loss']
val_acc = cnn_1.history['val_accuracy']

fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(10, 5))
sns.lineplot(x=cnn_1.epoch, y=train_loss, ax=ax1, label='train_loss')
sns.lineplot(x=cnn_1.epoch, y=train_acc, ax=ax2, label='train_accuracy')
sns.lineplot(x=cnn_1.epoch, y=val_loss, ax=ax1, label='val_loss')
sns.lineplot(x=cnn_1.epoch, y=val_acc, ax=ax2, label='val_accuracy')
```

Out[48]: <AxesSubplot: >



```
In [49]: def build_cnn():
    model = models.Sequential()
    model.add(layers.Conv2D(32, (3, 3), activation='relu', input_shape=(64, 64, 3)))
    model.add(layers.MaxPooling2D((2, 2)))

    model.add(layers.Conv2D(32, (4, 4), activation='relu'))
    model.add(layers.MaxPooling2D((2, 2)))

    model.add(layers.Conv2D(64, (3, 3), activation='relu'))
    model.add(layers.MaxPooling2D((2, 2)))

    model.add(layers.Flatten())
    model.add(layers.Dense(64, activation='relu'))
    model.add(layers.Dense(1, activation='sigmoid')) #Last layer must be 1 for binary classification

    model.compile(loss='binary_crossentropy',
                  optimizer='sgd',
                  metrics=['accuracy'])

    return model
```

```
In [50]: keras_model2 = sci ki t_ l earn. KerasCl assi fi er(bui l d_cnn,  
                                                            epochs=25,  
                                                            val idati on_data=(val id_i mages,  
val id_y),  
                                                            val idati on_steps = val idati on_s  
i ze)
```

```
In [51]: # Now that it is a keras model, you can cross-validate it  
cvs = cross_val_score(keras_model2, train_images , train_y, cv=5)
```

Epoch 1/25  
82/82 [=====] - 6s 65ms/step - loss: 0.6009 - accuracy: 0.7211 - val\_loss: 0.5827 - val\_accuracy: 0.7304  
Epoch 2/25  
82/82 [=====] - 5s 62ms/step - loss: 0.5773 - accuracy: 0.7302 - val\_loss: 0.5685 - val\_accuracy: 0.7304  
Epoch 3/25  
82/82 [=====] - 5s 65ms/step - loss: 0.5601 - accuracy: 0.7306 - val\_loss: 0.5458 - val\_accuracy: 0.7304  
Epoch 4/25  
82/82 [=====] - 5s 61ms/step - loss: 0.5272 - accuracy: 0.7352 - val\_loss: 0.5546 - val\_accuracy: 0.8922  
Epoch 5/25  
82/82 [=====] - 5s 63ms/step - loss: 0.4792 - accuracy: 0.7707 - val\_loss: 0.4053 - val\_accuracy: 0.8615  
Epoch 6/25  
82/82 [=====] - 5s 62ms/step - loss: 0.4322 - accuracy: 0.8063 - val\_loss: 0.3449 - val\_accuracy: 0.8407  
Epoch 7/25  
82/82 [=====] - 5s 63ms/step - loss: 0.3752 - accuracy: 0.8349 - val\_loss: 0.3575 - val\_accuracy: 0.8150  
Epoch 8/25  
82/82 [=====] - 5s 61ms/step - loss: 0.3535 - accuracy: 0.8380 - val\_loss: 0.2952 - val\_accuracy: 0.8848  
Epoch 9/25  
82/82 [=====] - 5s 67ms/step - loss: 0.2903 - accuracy: 0.8838 - val\_loss: 0.3586 - val\_accuracy: 0.8297  
Epoch 10/25  
82/82 [=====] - 5s 65ms/step - loss: 0.2564 - accuracy: 0.8957 - val\_loss: 0.2603 - val\_accuracy: 0.8873  
Epoch 11/25  
82/82 [=====] - 5s 65ms/step - loss: 0.2393 - accuracy: 0.9064 - val\_loss: 0.2823 - val\_accuracy: 0.8701  
Epoch 12/25  
82/82 [=====] - 5s 64ms/step - loss: 0.2330 - accuracy: 0.9087 - val\_loss: 0.2199 - val\_accuracy: 0.9069  
Epoch 13/25  
82/82 [=====] - 6s 69ms/step - loss: 0.2165 - accuracy: 0.9194 - val\_loss: 0.1922 - val\_accuracy: 0.9265  
Epoch 14/25  
82/82 [=====] - 5s 63ms/step - loss: 0.2064 - accuracy: 0.9178 - val\_loss: 0.1838 - val\_accuracy: 0.9301  
Epoch 15/25  
82/82 [=====] - 5s 58ms/step - loss: 0.2060 - accuracy: 0.9171 - val\_loss: 0.1785 - val\_accuracy: 0.9289  
Epoch 16/25  
82/82 [=====] - 5s 63ms/step - loss: 0.1975 - accuracy: 0.9217 - val\_loss: 0.1874 - val\_accuracy: 0.9265  
Epoch 17/25  
82/82 [=====] - 5s 64ms/step - loss: 0.1958 - accuracy: 0.9240 - val\_loss: 0.2169 - val\_accuracy: 0.9007  
Epoch 18/25  
82/82 [=====] - 5s 63ms/step - loss: 0.1982 - accuracy: 0.9205 - val\_loss: 0.1729 - val\_accuracy: 0.9387  
Epoch 19/25  
82/82 [=====] - 6s 69ms/step - loss: 0.1882 - accuracy:

racy: 0.9251 - val\_loss: 0.1952 - val\_accuracy: 0.9350  
Epoch 20/25  
82/82 [=====] - 5s 65ms/step - loss: 0.1802 - accu  
racy: 0.9327 - val\_loss: 0.1596 - val\_accuracy: 0.9363  
Epoch 21/25  
82/82 [=====] - 5s 63ms/step - loss: 0.1757 - accu  
racy: 0.9297 - val\_loss: 0.1566 - val\_accuracy: 0.9412  
Epoch 22/25  
82/82 [=====] - 5s 66ms/step - loss: 0.1759 - accu  
racy: 0.9320 - val\_loss: 0.1703 - val\_accuracy: 0.9338  
Epoch 23/25  
82/82 [=====] - 5s 61ms/step - loss: 0.1770 - accu  
racy: 0.9327 - val\_loss: 0.2033 - val\_accuracy: 0.9289  
Epoch 24/25  
82/82 [=====] - 5s 62ms/step - loss: 0.1709 - accu  
racy: 0.9335 - val\_loss: 0.1748 - val\_accuracy: 0.9375  
Epoch 25/25  
82/82 [=====] - 5s 64ms/step - loss: 0.1665 - accu  
racy: 0.9362 - val\_loss: 0.1918 - val\_accuracy: 0.9216  
21/21 [=====] - 1s 22ms/step - loss: 0.1977 - accu  
racy: 0.9206  
Epoch 1/25  
82/82 [=====] - 6s 68ms/step - loss: 0.5953 - accu  
racy: 0.7279 - val\_loss: 0.5846 - val\_accuracy: 0.7304  
Epoch 2/25  
82/82 [=====] - 5s 59ms/step - loss: 0.5796 - accu  
racy: 0.7279 - val\_loss: 0.5684 - val\_accuracy: 0.7304  
Epoch 3/25  
82/82 [=====] - 5s 62ms/step - loss: 0.5645 - accu  
racy: 0.7279 - val\_loss: 0.5454 - val\_accuracy: 0.7304  
Epoch 4/25  
82/82 [=====] - 5s 63ms/step - loss: 0.5301 - accu  
racy: 0.7279 - val\_loss: 0.4839 - val\_accuracy: 0.7304  
Epoch 5/25  
82/82 [=====] - 5s 64ms/step - loss: 0.4891 - accu  
racy: 0.7681 - val\_loss: 0.4003 - val\_accuracy: 0.8051  
Epoch 6/25  
82/82 [=====] - 5s 64ms/step - loss: 0.4316 - accu  
racy: 0.8089 - val\_loss: 0.4034 - val\_accuracy: 0.8554  
Epoch 7/25  
82/82 [=====] - 6s 70ms/step - loss: 0.3918 - accu  
racy: 0.8296 - val\_loss: 0.3013 - val\_accuracy: 0.8652  
Epoch 8/25  
82/82 [=====] - 5s 65ms/step - loss: 0.3258 - accu  
racy: 0.8624 - val\_loss: 0.2638 - val\_accuracy: 0.8909  
Epoch 9/25  
82/82 [=====] - 5s 64ms/step - loss: 0.2717 - accu  
racy: 0.8827 - val\_loss: 0.2755 - val\_accuracy: 0.8811  
Epoch 10/25  
82/82 [=====] - 5s 67ms/step - loss: 0.2587 - accu  
racy: 0.8869 - val\_loss: 0.3643 - val\_accuracy: 0.8468  
Epoch 11/25  
82/82 [=====] - 5s 60ms/step - loss: 0.2378 - accu  
racy: 0.9071 - val\_loss: 0.2455 - val\_accuracy: 0.8934  
Epoch 12/25  
82/82 [=====] - 5s 62ms/step - loss: 0.2235 - accu



racy: 0.9075 - val\_loss: 0.2274 - val\_accuracy: 0.9032  
Epoch 13/25  
82/82 [=====] - 5s 67ms/step - loss: 0.2137 - accu  
racy: 0.9121 - val\_loss: 0.1746 - val\_accuracy: 0.9326  
Epoch 14/25  
82/82 [=====] - 6s 68ms/step - loss: 0.2017 - accu  
racy: 0.9217 - val\_loss: 0.1750 - val\_accuracy: 0.9350  
Epoch 15/25  
82/82 [=====] - 5s 66ms/step - loss: 0.2091 - accu  
racy: 0.9159 - val\_loss: 0.1710 - val\_accuracy: 0.9326  
Epoch 16/25  
82/82 [=====] - 5s 67ms/step - loss: 0.1993 - accu  
racy: 0.9190 - val\_loss: 0.1684 - val\_accuracy: 0.9436  
Epoch 17/25  
82/82 [=====] - 5s 65ms/step - loss: 0.1914 - accu  
racy: 0.9224 - val\_loss: 0.1563 - val\_accuracy: 0.9400  
Epoch 18/25  
82/82 [=====] - 5s 60ms/step - loss: 0.1851 - accu  
racy: 0.9251 - val\_loss: 0.1528 - val\_accuracy: 0.9436  
Epoch 19/25  
82/82 [=====] - 6s 67ms/step - loss: 0.1863 - accu  
racy: 0.9243 - val\_loss: 0.1711 - val\_accuracy: 0.9375  
Epoch 20/25  
82/82 [=====] - 5s 65ms/step - loss: 0.1757 - accu  
racy: 0.9274 - val\_loss: 0.1553 - val\_accuracy: 0.9412  
Epoch 21/25  
82/82 [=====] - 5s 64ms/step - loss: 0.1819 - accu  
racy: 0.9282 - val\_loss: 0.1478 - val\_accuracy: 0.9534  
Epoch 22/25  
82/82 [=====] - 5s 63ms/step - loss: 0.1761 - accu  
racy: 0.9312 - val\_loss: 0.1425 - val\_accuracy: 0.9498  
Epoch 23/25  
82/82 [=====] - 5s 65ms/step - loss: 0.1745 - accu  
racy: 0.9327 - val\_loss: 0.1413 - val\_accuracy: 0.9534  
Epoch 24/25  
82/82 [=====] - 6s 70ms/step - loss: 0.1650 - accu  
racy: 0.9339 - val\_loss: 0.1643 - val\_accuracy: 0.9412  
Epoch 25/25  
82/82 [=====] - 5s 63ms/step - loss: 0.1602 - accu  
racy: 0.9343 - val\_loss: 0.1548 - val\_accuracy: 0.9461  
21/21 [=====] - 0s 17ms/step - loss: 0.1635 - accu  
racy: 0.9405  
Epoch 1/25  
82/82 [=====] - 6s 66ms/step - loss: 0.5821 - accu  
racy: 0.7311 - val\_loss: 0.5716 - val\_accuracy: 0.7304  
Epoch 2/25  
82/82 [=====] - 5s 62ms/step - loss: 0.5592 - accu  
racy: 0.7311 - val\_loss: 0.5571 - val\_accuracy: 0.7304  
Epoch 3/25  
82/82 [=====] - 5s 62ms/step - loss: 0.5338 - accu  
racy: 0.7315 - val\_loss: 0.5010 - val\_accuracy: 0.7439  
Epoch 4/25  
82/82 [=====] - 5s 67ms/step - loss: 0.4800 - accu  
racy: 0.7716 - val\_loss: 0.4128 - val\_accuracy: 0.8505  
Epoch 5/25  
82/82 [=====] - 5s 64ms/step - loss: 0.4466 - accu

racy: 0.8006 - val\_loss: 0.5234 - val\_accuracy: 0.7549  
Epoch 6/25  
82/82 [=====] - 5s 63ms/step - loss: 0.3757 - accu  
racy: 0.8403 - val\_loss: 0.2938 - val\_accuracy: 0.8873  
Epoch 7/25  
82/82 [=====] - 5s 65ms/step - loss: 0.3228 - accu  
racy: 0.8606 - val\_loss: 0.3138 - val\_accuracy: 0.8480  
Epoch 8/25  
82/82 [=====] - 5s 64ms/step - loss: 0.2889 - accu  
racy: 0.8747 - val\_loss: 0.2307 - val\_accuracy: 0.9056  
Epoch 9/25  
82/82 [=====] - 5s 62ms/step - loss: 0.2612 - accu  
racy: 0.8934 - val\_loss: 0.2153 - val\_accuracy: 0.9130  
Epoch 10/25  
82/82 [=====] - 5s 67ms/step - loss: 0.2301 - accu  
racy: 0.9072 - val\_loss: 0.2738 - val\_accuracy: 0.8860  
Epoch 11/25  
82/82 [=====] - 5s 66ms/step - loss: 0.2319 - accu  
racy: 0.9083 - val\_loss: 0.2217 - val\_accuracy: 0.9020  
Epoch 12/25  
82/82 [=====] - 5s 63ms/step - loss: 0.2092 - accu  
racy: 0.9198 - val\_loss: 0.1750 - val\_accuracy: 0.9301  
Epoch 13/25  
82/82 [=====] - 5s 66ms/step - loss: 0.2057 - accu  
racy: 0.9194 - val\_loss: 0.1714 - val\_accuracy: 0.9350  
Epoch 14/25  
82/82 [=====] - 5s 65ms/step - loss: 0.1909 - accu  
racy: 0.9274 - val\_loss: 0.1603 - val\_accuracy: 0.9387  
Epoch 15/25  
82/82 [=====] - 6s 71ms/step - loss: 0.1921 - accu  
racy: 0.9225 - val\_loss: 0.2564 - val\_accuracy: 0.8909  
Epoch 16/25  
82/82 [=====] - 5s 65ms/step - loss: 0.1870 - accu  
racy: 0.9320 - val\_loss: 0.1806 - val\_accuracy: 0.9301  
Epoch 17/25  
82/82 [=====] - 5s 67ms/step - loss: 0.1851 - accu  
racy: 0.9297 - val\_loss: 0.1578 - val\_accuracy: 0.9350  
Epoch 18/25  
82/82 [=====] - 5s 63ms/step - loss: 0.1811 - accu  
racy: 0.9293 - val\_loss: 0.1474 - val\_accuracy: 0.9498  
Epoch 19/25  
82/82 [=====] - 6s 69ms/step - loss: 0.1728 - accu  
racy: 0.9354 - val\_loss: 0.1440 - val\_accuracy: 0.9510  
Epoch 20/25  
82/82 [=====] - 5s 67ms/step - loss: 0.1740 - accu  
racy: 0.9358 - val\_loss: 0.1632 - val\_accuracy: 0.9387  
Epoch 21/25  
82/82 [=====] - 5s 65ms/step - loss: 0.1738 - accu  
racy: 0.9381 - val\_loss: 0.1381 - val\_accuracy: 0.9522  
Epoch 22/25  
82/82 [=====] - 5s 62ms/step - loss: 0.1709 - accu  
racy: 0.9358 - val\_loss: 0.2043 - val\_accuracy: 0.9167  
Epoch 23/25  
82/82 [=====] - 5s 61ms/step - loss: 0.1647 - accu  
racy: 0.9412 - val\_loss: 0.1372 - val\_accuracy: 0.9571  
Epoch 24/25

82/82 [=====] - 5s 65ms/step - loss: 0.1671 - accuracy: 0.9354 - val\_loss: 0.1368 - val\_accuracy: 0.9461  
Epoch 25/25  
82/82 [=====] - 5s 67ms/step - loss: 0.1621 - accuracy: 0.9435 - val\_loss: 0.1538 - val\_accuracy: 0.9412  
21/21 [=====] - 1s 19ms/step - loss: 0.1717 - accuracy: 0.9312  
Epoch 1/25  
82/82 [=====] - 6s 72ms/step - loss: 0.5875 - accuracy: 0.7288 - val\_loss: 0.5736 - val\_accuracy: 0.7304  
Epoch 2/25  
82/82 [=====] - 5s 66ms/step - loss: 0.5586 - accuracy: 0.7357 - val\_loss: 0.5433 - val\_accuracy: 0.7304  
Epoch 3/25  
82/82 [=====] - 5s 67ms/step - loss: 0.5217 - accuracy: 0.7437 - val\_loss: 0.4769 - val\_accuracy: 0.7525  
Epoch 4/25  
82/82 [=====] - 5s 65ms/step - loss: 0.4551 - accuracy: 0.7953 - val\_loss: 0.5278 - val\_accuracy: 0.7549  
Epoch 5/25  
82/82 [=====] - 5s 63ms/step - loss: 0.4057 - accuracy: 0.8178 - val\_loss: 0.3089 - val\_accuracy: 0.9130  
Epoch 6/25  
82/82 [=====] - 5s 65ms/step - loss: 0.3353 - accuracy: 0.8610 - val\_loss: 0.2534 - val\_accuracy: 0.9081  
Epoch 7/25  
82/82 [=====] - 5s 60ms/step - loss: 0.2928 - accuracy: 0.8774 - val\_loss: 0.2451 - val\_accuracy: 0.9093  
Epoch 8/25  
82/82 [=====] - 5s 65ms/step - loss: 0.2517 - accuracy: 0.8950 - val\_loss: 0.2375 - val\_accuracy: 0.9044  
Epoch 9/25  
82/82 [=====] - 5s 65ms/step - loss: 0.2338 - accuracy: 0.9022 - val\_loss: 0.1917 - val\_accuracy: 0.9252  
Epoch 10/25  
82/82 [=====] - 5s 63ms/step - loss: 0.2071 - accuracy: 0.9179 - val\_loss: 0.1795 - val\_accuracy: 0.9277  
Epoch 11/25  
82/82 [=====] - 5s 60ms/step - loss: 0.2022 - accuracy: 0.9163 - val\_loss: 0.1922 - val\_accuracy: 0.9167  
Epoch 12/25  
82/82 [=====] - 5s 65ms/step - loss: 0.1924 - accuracy: 0.9209 - val\_loss: 0.1636 - val\_accuracy: 0.9338  
Epoch 13/25  
82/82 [=====] - 5s 65ms/step - loss: 0.1873 - accuracy: 0.9228 - val\_loss: 0.3901 - val\_accuracy: 0.8186  
Epoch 14/25  
82/82 [=====] - 5s 66ms/step - loss: 0.1825 - accuracy: 0.9274 - val\_loss: 0.1569 - val\_accuracy: 0.9363  
Epoch 15/25  
82/82 [=====] - 5s 64ms/step - loss: 0.1752 - accuracy: 0.9297 - val\_loss: 0.1581 - val\_accuracy: 0.9400  
Epoch 16/25  
82/82 [=====] - 5s 66ms/step - loss: 0.1666 - accuracy: 0.9347 - val\_loss: 0.1770 - val\_accuracy: 0.9387  
Epoch 17/25

82/82 [=====] - 5s 63ms/step - loss: 0.1722 - accuracy: 0.9339 - val\_loss: 0.1497 - val\_accuracy: 0.9473  
Epoch 18/25  
82/82 [=====] - 5s 65ms/step - loss: 0.1553 - accuracy: 0.9385 - val\_loss: 0.1836 - val\_accuracy: 0.9338  
Epoch 19/25  
82/82 [=====] - 5s 64ms/step - loss: 0.1621 - accuracy: 0.9339 - val\_loss: 0.1470 - val\_accuracy: 0.9436  
Epoch 20/25  
82/82 [=====] - 5s 63ms/step - loss: 0.1597 - accuracy: 0.9370 - val\_loss: 0.2571 - val\_accuracy: 0.9032  
Epoch 21/25  
82/82 [=====] - 5s 64ms/step - loss: 0.1501 - accuracy: 0.9427 - val\_loss: 0.1371 - val\_accuracy: 0.9498  
Epoch 22/25  
82/82 [=====] - 5s 64ms/step - loss: 0.1520 - accuracy: 0.9396 - val\_loss: 0.1365 - val\_accuracy: 0.9510  
Epoch 23/25  
82/82 [=====] - 5s 64ms/step - loss: 0.1444 - accuracy: 0.9446 - val\_loss: 0.1508 - val\_accuracy: 0.9498  
Epoch 24/25  
82/82 [=====] - 5s 67ms/step - loss: 0.1403 - accuracy: 0.9431 - val\_loss: 0.1311 - val\_accuracy: 0.9522  
Epoch 25/25  
82/82 [=====] - 5s 64ms/step - loss: 0.1456 - accuracy: 0.9435 - val\_loss: 0.1484 - val\_accuracy: 0.9473  
21/21 [=====] - 0s 17ms/step - loss: 0.2138 - accuracy: 0.9159  
Epoch 1/25  
82/82 [=====] - 6s 65ms/step - loss: 0.6044 - accuracy: 0.7147 - val\_loss: 0.5787 - val\_accuracy: 0.7304  
Epoch 2/25  
82/82 [=====] - 5s 65ms/step - loss: 0.5763 - accuracy: 0.7273 - val\_loss: 0.5836 - val\_accuracy: 0.7304  
Epoch 3/25  
82/82 [=====] - 6s 69ms/step - loss: 0.5595 - accuracy: 0.7273 - val\_loss: 0.5525 - val\_accuracy: 0.7304  
Epoch 4/25  
82/82 [=====] - 6s 68ms/step - loss: 0.5251 - accuracy: 0.7288 - val\_loss: 0.4779 - val\_accuracy: 0.7439  
Epoch 5/25  
82/82 [=====] - 5s 62ms/step - loss: 0.4799 - accuracy: 0.7639 - val\_loss: 0.5578 - val\_accuracy: 0.7304  
Epoch 6/25  
82/82 [=====] - 5s 63ms/step - loss: 0.4119 - accuracy: 0.8251 - val\_loss: 0.3320 - val\_accuracy: 0.8566  
Epoch 7/25  
82/82 [=====] - 6s 68ms/step - loss: 0.3720 - accuracy: 0.8338 - val\_loss: 0.3122 - val\_accuracy: 0.8615  
Epoch 8/25  
82/82 [=====] - 5s 67ms/step - loss: 0.3170 - accuracy: 0.8694 - val\_loss: 0.2652 - val\_accuracy: 0.8909  
Epoch 9/25  
82/82 [=====] - 5s 62ms/step - loss: 0.2915 - accuracy: 0.8793 - val\_loss: 0.2358 - val\_accuracy: 0.9044  
Epoch 10/25

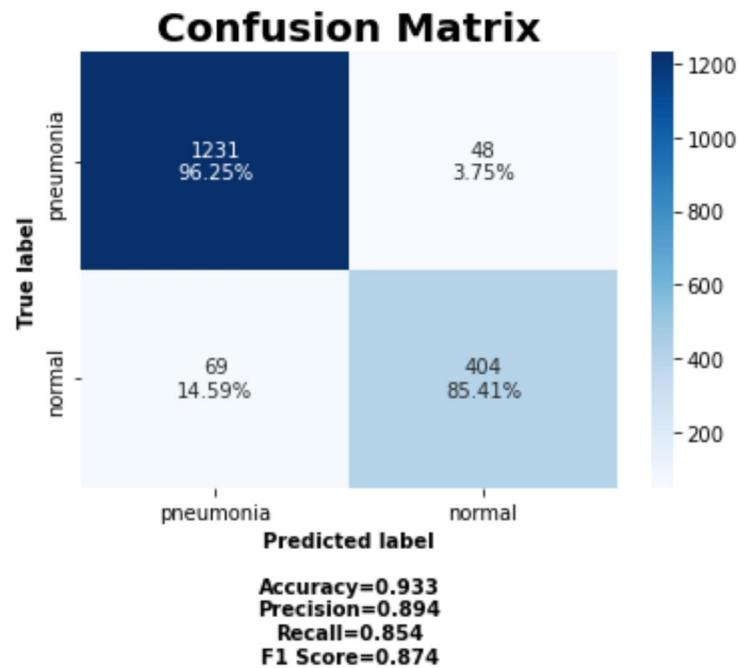
82/82 [=====] - 5s 67ms/step - loss: 0.2720 - accuracy: 0.8885 - val\_loss: 0.2335 - val\_accuracy: 0.8995  
Epoch 11/25  
82/82 [=====] - 5s 64ms/step - loss: 0.2445 - accuracy: 0.8988 - val\_loss: 0.2661 - val\_accuracy: 0.8787  
Epoch 12/25  
82/82 [=====] - 5s 64ms/step - loss: 0.2357 - accuracy: 0.9053 - val\_loss: 0.1893 - val\_accuracy: 0.9191  
Epoch 13/25  
82/82 [=====] - 5s 62ms/step - loss: 0.2165 - accuracy: 0.9141 - val\_loss: 0.1851 - val\_accuracy: 0.9265  
Epoch 14/25  
82/82 [=====] - 5s 66ms/step - loss: 0.2128 - accuracy: 0.9206 - val\_loss: 0.1763 - val\_accuracy: 0.9314  
Epoch 15/25  
82/82 [=====] - 5s 66ms/step - loss: 0.2162 - accuracy: 0.9144 - val\_loss: 0.1779 - val\_accuracy: 0.9314  
Epoch 16/25  
82/82 [=====] - 5s 66ms/step - loss: 0.1990 - accuracy: 0.9240 - val\_loss: 0.1695 - val\_accuracy: 0.9338  
Epoch 17/25  
82/82 [=====] - 5s 65ms/step - loss: 0.1937 - accuracy: 0.9255 - val\_loss: 0.1611 - val\_accuracy: 0.9387  
Epoch 18/25  
82/82 [=====] - 5s 62ms/step - loss: 0.1972 - accuracy: 0.9263 - val\_loss: 0.1586 - val\_accuracy: 0.9387  
Epoch 19/25  
82/82 [=====] - 5s 64ms/step - loss: 0.1877 - accuracy: 0.9267 - val\_loss: 0.1513 - val\_accuracy: 0.9350  
Epoch 20/25  
82/82 [=====] - 5s 67ms/step - loss: 0.1817 - accuracy: 0.9293 - val\_loss: 0.1478 - val\_accuracy: 0.9375  
Epoch 21/25  
82/82 [=====] - 5s 61ms/step - loss: 0.1857 - accuracy: 0.9301 - val\_loss: 0.1502 - val\_accuracy: 0.9485  
Epoch 22/25  
82/82 [=====] - 5s 67ms/step - loss: 0.1796 - accuracy: 0.9297 - val\_loss: 0.1429 - val\_accuracy: 0.9449  
Epoch 23/25  
82/82 [=====] - 5s 63ms/step - loss: 0.1745 - accuracy: 0.9343 - val\_loss: 0.1533 - val\_accuracy: 0.9412  
Epoch 24/25  
82/82 [=====] - 5s 64ms/step - loss: 0.1785 - accuracy: 0.9324 - val\_loss: 0.1415 - val\_accuracy: 0.9473  
Epoch 25/25  
82/82 [=====] - 5s 64ms/step - loss: 0.1693 - accuracy: 0.9374 - val\_loss: 0.1453 - val\_accuracy: 0.9510

```
In [52]: save_result('CNN #1', results_train[1], results_test[1], cvs[0], cvs[1], cvs[2], cvs[3], cvs[4])
```

Out[52]:

	model_name	Train Accuracy	Test Accuracy	CV1	CV2	CV3	CV4	CV5	CV_Std	CV_avg
0	CNN #1	0.953	0.933	0.921	0.94	0.931	0.916	0.945	0.012	0.931
0	Initial Model	0.730	0.730	0.925	0.74	0.728	0.709	0.743	0.088	0.769

```
In [53]: cm_plot_labels = ['pneumonia', 'normal']  
make_confusion_matrix(cm, categories = cm_plot_labels, title='Confusion Matrix')
```



## CNN Model 2

For this model, I added another round of Conv2D and MaxPooling layers, and changed the optimizer to "adam"

```
In [54]: model 2 = models.Sequential()

model 2.add(layers.Conv2D(32, (3, 3), activation='relu',
                           input_shape=(64, 64, 3)))
model 2.add(layers.MaxPooling2D((2, 2)))

model 2.add(layers.Conv2D(32, (4, 4), activation='relu'))
model 2.add(layers.MaxPooling2D((2, 2)))

model 2.add(layers.Conv2D(64, (3, 3), activation='relu'))
model 2.add(layers.MaxPooling2D((2, 2)))

model 2.add(layers.Conv2D(96, (3, 3), activation='relu'))
model 2.add(layers.MaxPooling2D((2, 2)))

model 2.add(layers.Flatten())
model 2.add(layers.Dense(64, activation='relu'))
model 2.add(layers.Dense(1, activation='sigmoid'))

model 2.compile(loss='binary_crossentropy',
                 optimizer="adam",
                 metrics=['accuracy'])
```

[illegible]



Epoch 1/50  
103/103 [=====] - 6s 59ms/step - loss: 0.5266 - accuracy: 0.7540 - val\_loss: 0.3215 - val\_accuracy: 0.8468  
Epoch 2/50  
103/103 [=====] - 5s 53ms/step - loss: 0.2640 - accuracy: 0.8860 - val\_loss: 0.2662 - val\_accuracy: 0.8873  
Epoch 3/50  
103/103 [=====] - 5s 53ms/step - loss: 0.2020 - accuracy: 0.9166 - val\_loss: 0.1455 - val\_accuracy: 0.9461  
Epoch 4/50  
103/103 [=====] - 5s 52ms/step - loss: 0.1562 - accuracy: 0.9410 - val\_loss: 0.2715 - val\_accuracy: 0.8897  
Epoch 5/50  
103/103 [=====] - 5s 52ms/step - loss: 0.1672 - accuracy: 0.9337 - val\_loss: 0.1343 - val\_accuracy: 0.9596  
Epoch 6/50  
103/103 [=====] - 5s 54ms/step - loss: 0.1204 - accuracy: 0.9548 - val\_loss: 0.1505 - val\_accuracy: 0.9461  
Epoch 7/50  
103/103 [=====] - 5s 51ms/step - loss: 0.1124 - accuracy: 0.9590 - val\_loss: 0.1110 - val\_accuracy: 0.9632  
Epoch 8/50  
103/103 [=====] - 6s 54ms/step - loss: 0.1135 - accuracy: 0.9603 - val\_loss: 0.1105 - val\_accuracy: 0.9669  
Epoch 9/50  
103/103 [=====] - 5s 53ms/step - loss: 0.1085 - accuracy: 0.9624 - val\_loss: 0.1213 - val\_accuracy: 0.9632  
Epoch 10/50  
103/103 [=====] - 6s 54ms/step - loss: 0.1028 - accuracy: 0.9649 - val\_loss: 0.1054 - val\_accuracy: 0.9669  
Epoch 11/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0838 - accuracy: 0.9679 - val\_loss: 0.1388 - val\_accuracy: 0.9645  
Epoch 12/50  
103/103 [=====] - 6s 54ms/step - loss: 0.0964 - accuracy: 0.9664 - val\_loss: 0.1025 - val\_accuracy: 0.9681  
Epoch 13/50  
103/103 [=====] - 5s 53ms/step - loss: 0.0720 - accuracy: 0.9731 - val\_loss: 0.1562 - val\_accuracy: 0.9583  
Epoch 14/50  
103/103 [=====] - 5s 51ms/step - loss: 0.0773 - accuracy: 0.9688 - val\_loss: 0.1066 - val\_accuracy: 0.9669  
Epoch 15/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0608 - accuracy: 0.9789 - val\_loss: 0.1061 - val\_accuracy: 0.9694  
Epoch 16/50  
103/103 [=====] - 6s 54ms/step - loss: 0.0534 - accuracy: 0.9817 - val\_loss: 0.1152 - val\_accuracy: 0.9669  
Epoch 17/50  
103/103 [=====] - 5s 52ms/step - loss: 0.0562 - accuracy: 0.9820 - val\_loss: 0.1231 - val\_accuracy: 0.9645  
Epoch 18/50  
103/103 [=====] - 5s 51ms/step - loss: 0.0497 - accuracy: 0.9798 - val\_loss: 0.1026 - val\_accuracy: 0.9645  
Epoch 19/50  
103/103 [=====] - 6s 55ms/step - loss: 0.0406 - ac

curacy: 0.9875 - val\_loss: 0.1273 - val\_accuracy: 0.9669  
Epoch 20/50  
103/103 [=====] - 5s 50ms/step - loss: 0.0358 - accuracy: 0.9884 - val\_loss: 0.1104 - val\_accuracy: 0.9718  
Epoch 21/50  
103/103 [=====] - 6s 55ms/step - loss: 0.0257 - accuracy: 0.9930 - val\_loss: 0.1134 - val\_accuracy: 0.9681  
Epoch 22/50  
103/103 [=====] - 5s 52ms/step - loss: 0.0225 - accuracy: 0.9936 - val\_loss: 0.1204 - val\_accuracy: 0.9681  
Epoch 23/50  
103/103 [=====] - 5s 51ms/step - loss: 0.0174 - accuracy: 0.9948 - val\_loss: 0.1634 - val\_accuracy: 0.9669  
Epoch 24/50  
103/103 [=====] - 5s 51ms/step - loss: 0.0260 - accuracy: 0.9911 - val\_loss: 0.1348 - val\_accuracy: 0.9718  
Epoch 25/50  
103/103 [=====] - 5s 52ms/step - loss: 0.0264 - accuracy: 0.9911 - val\_loss: 0.2021 - val\_accuracy: 0.9498  
Epoch 26/50  
103/103 [=====] - 5s 50ms/step - loss: 0.0367 - accuracy: 0.9841 - val\_loss: 0.1406 - val\_accuracy: 0.9657  
Epoch 27/50  
103/103 [=====] - 5s 52ms/step - loss: 0.0176 - accuracy: 0.9954 - val\_loss: 0.2006 - val\_accuracy: 0.9645  
Epoch 28/50  
103/103 [=====] - 5s 52ms/step - loss: 0.0096 - accuracy: 0.9976 - val\_loss: 0.1606 - val\_accuracy: 0.9645  
Epoch 29/50  
103/103 [=====] - 5s 53ms/step - loss: 0.0032 - accuracy: 0.9994 - val\_loss: 0.1703 - val\_accuracy: 0.9730  
Epoch 30/50  
103/103 [=====] - 6s 54ms/step - loss: 0.0027 - accuracy: 0.9997 - val\_loss: 0.1845 - val\_accuracy: 0.9657  
Epoch 31/50  
103/103 [=====] - 5s 52ms/step - loss: 9.1708e-04 - accuracy: 1.0000 - val\_loss: 0.1858 - val\_accuracy: 0.9681  
Epoch 32/50  
103/103 [=====] - 5s 52ms/step - loss: 6.6034e-04 - accuracy: 1.0000 - val\_loss: 0.1947 - val\_accuracy: 0.9657  
Epoch 33/50  
103/103 [=====] - 5s 52ms/step - loss: 5.2490e-04 - accuracy: 1.0000 - val\_loss: 0.1947 - val\_accuracy: 0.9694  
Epoch 34/50  
103/103 [=====] - 6s 55ms/step - loss: 4.3404e-04 - accuracy: 1.0000 - val\_loss: 0.1987 - val\_accuracy: 0.9694  
Epoch 35/50  
103/103 [=====] - 5s 50ms/step - loss: 3.4267e-04 - accuracy: 1.0000 - val\_loss: 0.2037 - val\_accuracy: 0.9694  
Epoch 36/50  
103/103 [=====] - 5s 50ms/step - loss: 2.8119e-04 - accuracy: 1.0000 - val\_loss: 0.2100 - val\_accuracy: 0.9694  
Epoch 37/50  
103/103 [=====] - 5s 52ms/step - loss: 2.4515e-04 - accuracy: 1.0000 - val\_loss: 0.2166 - val\_accuracy: 0.9681  
Epoch 38/50

```

103/103 [=====] - 5s 52ms/step - loss: 2.1776e-04
- accuracy: 1.0000 - val_loss: 0.2206 - val_accuracy: 0.9681
Epoch 39/50
103/103 [=====] - 5s 52ms/step - loss: 1.8785e-04
- accuracy: 1.0000 - val_loss: 0.2208 - val_accuracy: 0.9694
Epoch 40/50
103/103 [=====] - 6s 54ms/step - loss: 1.6931e-04
- accuracy: 1.0000 - val_loss: 0.2233 - val_accuracy: 0.9694
Epoch 41/50
103/103 [=====] - 5s 49ms/step - loss: 1.5455e-04
- accuracy: 1.0000 - val_loss: 0.2267 - val_accuracy: 0.9694
Epoch 42/50
103/103 [=====] - 5s 49ms/step - loss: 1.3261e-04
- accuracy: 1.0000 - val_loss: 0.2329 - val_accuracy: 0.9694
Epoch 43/50
103/103 [=====] - 5s 52ms/step - loss: 1.1975e-04
- accuracy: 1.0000 - val_loss: 0.2370 - val_accuracy: 0.9694
Epoch 44/50
103/103 [=====] - 6s 55ms/step - loss: 1.0241e-04
- accuracy: 1.0000 - val_loss: 0.2374 - val_accuracy: 0.9694
Epoch 45/50
103/103 [=====] - 6s 55ms/step - loss: 9.7684e-05
- accuracy: 1.0000 - val_loss: 0.2398 - val_accuracy: 0.9694
Epoch 46/50
103/103 [=====] - 5s 48ms/step - loss: 8.3875e-05
- accuracy: 1.0000 - val_loss: 0.2450 - val_accuracy: 0.9694
Epoch 47/50
103/103 [=====] - 5s 52ms/step - loss: 7.6287e-05
- accuracy: 1.0000 - val_loss: 0.2477 - val_accuracy: 0.9694
Epoch 48/50
103/103 [=====] - 5s 53ms/step - loss: 6.7424e-05
- accuracy: 1.0000 - val_loss: 0.2482 - val_accuracy: 0.9694
Epoch 49/50
103/103 [=====] - 5s 50ms/step - loss: 6.1867e-05
- accuracy: 1.0000 - val_loss: 0.2519 - val_accuracy: 0.9694
Epoch 50/50
103/103 [=====] - 6s 54ms/step - loss: 5.5456e-05
- accuracy: 1.0000 - val_loss: 0.2574 - val_accuracy: 0.9694

```

```
In [56]: results_train = model2.evaluate(train_images, train_y)
```

```

103/103 [=====] - 1s 8ms/step - loss: 5.1945e-05 -
accuracy: 1.0000

```

```
In [57]: results_test = model2.evaluate(test_images, test_y)
```

```

55/55 [=====] - 0s 8ms/step - loss: 0.4235 - accur
acy: 0.9475

```

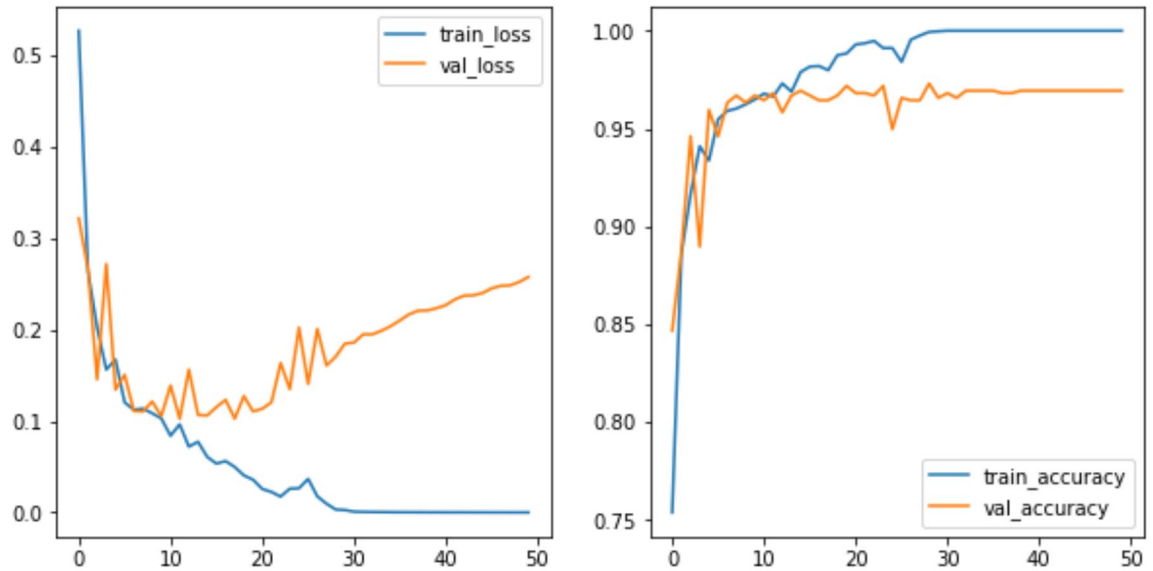
```

In [58]: train_loss = history.history['loss']
train_acc = history.history['accuracy']
val_loss = history.history['val_loss']
val_acc = history.history['val_accuracy']

fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(10, 5))
sns.lineplot(x=history.epoch, y=train_loss, ax=ax1, label='train_loss')
sns.lineplot(x=history.epoch, y=train_acc, ax=ax2, label='train_accuracy')
sns.lineplot(x=history.epoch, y=val_loss, ax=ax1, label='val_loss')
sns.lineplot(x=history.epoch, y=val_acc, ax=ax2, label='val_accuracy')

```

Out[58]: <AxesSubplot: >





```
In [61]: cvs = cross_val_score(keras_model3, train_images , train_y, cv=5)
```

Epoch 1/50  
82/82 [=====] - 5s 59ms/step - loss: 0.5942 - accuracy: 0.7272 - val\_loss: 0.5344 - val\_accuracy: 0.7304  
Epoch 2/50  
82/82 [=====] - 4s 53ms/step - loss: 0.3410 - accuracy: 0.8514 - val\_loss: 0.3296 - val\_accuracy: 0.8529  
Epoch 3/50  
82/82 [=====] - 5s 56ms/step - loss: 0.2372 - accuracy: 0.8987 - val\_loss: 0.1711 - val\_accuracy: 0.9314  
Epoch 4/50  
82/82 [=====] - 4s 55ms/step - loss: 0.1770 - accuracy: 0.9301 - val\_loss: 0.1495 - val\_accuracy: 0.9571  
Epoch 5/50  
82/82 [=====] - 4s 51ms/step - loss: 0.1470 - accuracy: 0.9465 - val\_loss: 0.1098 - val\_accuracy: 0.9620  
Epoch 6/50  
82/82 [=====] - 5s 56ms/step - loss: 0.1182 - accuracy: 0.9587 - val\_loss: 0.1053 - val\_accuracy: 0.9632  
Epoch 7/50  
82/82 [=====] - 5s 56ms/step - loss: 0.1152 - accuracy: 0.9595 - val\_loss: 0.1107 - val\_accuracy: 0.9559  
Epoch 8/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0971 - accuracy: 0.9648 - val\_loss: 0.0985 - val\_accuracy: 0.9681  
Epoch 9/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0920 - accuracy: 0.9687 - val\_loss: 0.1020 - val\_accuracy: 0.9669  
Epoch 10/50  
82/82 [=====] - 4s 50ms/step - loss: 0.0965 - accuracy: 0.9641 - val\_loss: 0.1001 - val\_accuracy: 0.9669  
Epoch 11/50  
82/82 [=====] - 4s 55ms/step - loss: 0.1041 - accuracy: 0.9633 - val\_loss: 0.0931 - val\_accuracy: 0.9706  
Epoch 12/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0778 - accuracy: 0.9679 - val\_loss: 0.0974 - val\_accuracy: 0.9681  
Epoch 13/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0696 - accuracy: 0.9725 - val\_loss: 0.1128 - val\_accuracy: 0.9596  
Epoch 14/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0572 - accuracy: 0.9790 - val\_loss: 0.1025 - val\_accuracy: 0.9657  
Epoch 15/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0544 - accuracy: 0.9817 - val\_loss: 0.1039 - val\_accuracy: 0.9632  
Epoch 16/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0411 - accuracy: 0.9862 - val\_loss: 0.0996 - val\_accuracy: 0.9681  
Epoch 17/50  
82/82 [=====] - 5s 55ms/step - loss: 0.0323 - accuracy: 0.9916 - val\_loss: 0.0983 - val\_accuracy: 0.9718  
Epoch 18/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0348 - accuracy: 0.9878 - val\_loss: 0.0964 - val\_accuracy: 0.9706  
Epoch 19/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0293 - accuracy:

racy: 0.9904 - val\_loss: 0.1171 - val\_accuracy: 0.9620  
Epoch 20/50  
82/82 [=====] - 5s 55ms/step - loss: 0.0334 - accuracy: 0.9885 - val\_loss: 0.1255 - val\_accuracy: 0.9608  
Epoch 21/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0229 - accuracy: 0.9931 - val\_loss: 0.1003 - val\_accuracy: 0.9718  
Epoch 22/50  
82/82 [=====] - 4s 55ms/step - loss: 0.0144 - accuracy: 0.9969 - val\_loss: 0.1326 - val\_accuracy: 0.9645  
Epoch 23/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0165 - accuracy: 0.9943 - val\_loss: 0.1435 - val\_accuracy: 0.9645  
Epoch 24/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0242 - accuracy: 0.9889 - val\_loss: 0.2149 - val\_accuracy: 0.9498  
Epoch 25/50  
82/82 [=====] - 5s 55ms/step - loss: 0.0160 - accuracy: 0.9943 - val\_loss: 0.1601 - val\_accuracy: 0.9596  
Epoch 26/50  
82/82 [=====] - 4s 55ms/step - loss: 0.0115 - accuracy: 0.9973 - val\_loss: 0.1827 - val\_accuracy: 0.9645  
Epoch 27/50  
82/82 [=====] - 4s 51ms/step - loss: 0.0240 - accuracy: 0.9908 - val\_loss: 0.1555 - val\_accuracy: 0.9669  
Epoch 28/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0111 - accuracy: 0.9966 - val\_loss: 0.1663 - val\_accuracy: 0.9632  
Epoch 29/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0065 - accuracy: 0.9992 - val\_loss: 0.1884 - val\_accuracy: 0.9632  
Epoch 30/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0013 - accuracy: 1.0000 - val\_loss: 0.1889 - val\_accuracy: 0.9632  
Epoch 31/50  
82/82 [=====] - 4s 54ms/step - loss: 8.3831e-04 - accuracy: 1.0000 - val\_loss: 0.1667 - val\_accuracy: 0.9718  
Epoch 32/50  
82/82 [=====] - 4s 53ms/step - loss: 3.7506e-04 - accuracy: 1.0000 - val\_loss: 0.1732 - val\_accuracy: 0.9718  
Epoch 33/50  
82/82 [=====] - 5s 57ms/step - loss: 3.0090e-04 - accuracy: 1.0000 - val\_loss: 0.1766 - val\_accuracy: 0.9694  
Epoch 34/50  
82/82 [=====] - 5s 56ms/step - loss: 2.6013e-04 - accuracy: 1.0000 - val\_loss: 0.1787 - val\_accuracy: 0.9718  
Epoch 35/50  
82/82 [=====] - 4s 54ms/step - loss: 2.1732e-04 - accuracy: 1.0000 - val\_loss: 0.1829 - val\_accuracy: 0.9718  
Epoch 36/50  
82/82 [=====] - 5s 59ms/step - loss: 1.7739e-04 - accuracy: 1.0000 - val\_loss: 0.1872 - val\_accuracy: 0.9718  
Epoch 37/50  
82/82 [=====] - 4s 54ms/step - loss: 1.6035e-04 - accuracy: 1.0000 - val\_loss: 0.1895 - val\_accuracy: 0.9706  
Epoch 38/50



82/82 [=====] - 4s 54ms/step - loss: 1.4062e-04 - accuracy: 1.0000 - val\_loss: 0.1908 - val\_accuracy: 0.9718  
Epoch 39/50  
82/82 [=====] - 5s 55ms/step - loss: 1.2702e-04 - accuracy: 1.0000 - val\_loss: 0.1940 - val\_accuracy: 0.9706  
Epoch 40/50  
82/82 [=====] - 4s 52ms/step - loss: 1.1948e-04 - accuracy: 1.0000 - val\_loss: 0.1945 - val\_accuracy: 0.9718  
Epoch 41/50  
82/82 [=====] - 4s 54ms/step - loss: 1.0729e-04 - accuracy: 1.0000 - val\_loss: 0.1967 - val\_accuracy: 0.9718  
Epoch 42/50  
82/82 [=====] - 4s 53ms/step - loss: 9.8318e-05 - accuracy: 1.0000 - val\_loss: 0.1986 - val\_accuracy: 0.9718  
Epoch 43/50  
82/82 [=====] - 5s 57ms/step - loss: 9.3711e-05 - accuracy: 1.0000 - val\_loss: 0.2003 - val\_accuracy: 0.9718  
Epoch 44/50  
82/82 [=====] - 4s 54ms/step - loss: 8.3684e-05 - accuracy: 1.0000 - val\_loss: 0.2018 - val\_accuracy: 0.9718  
Epoch 45/50  
82/82 [=====] - 4s 55ms/step - loss: 7.6274e-05 - accuracy: 1.0000 - val\_loss: 0.2029 - val\_accuracy: 0.9730  
Epoch 46/50  
82/82 [=====] - 4s 54ms/step - loss: 7.5585e-05 - accuracy: 1.0000 - val\_loss: 0.2043 - val\_accuracy: 0.9718  
Epoch 47/50  
82/82 [=====] - 5s 56ms/step - loss: 7.1721e-05 - accuracy: 1.0000 - val\_loss: 0.2067 - val\_accuracy: 0.9718  
Epoch 48/50  
82/82 [=====] - 4s 54ms/step - loss: 6.3686e-05 - accuracy: 1.0000 - val\_loss: 0.2080 - val\_accuracy: 0.9718  
Epoch 49/50  
82/82 [=====] - 4s 54ms/step - loss: 5.9528e-05 - accuracy: 1.0000 - val\_loss: 0.2093 - val\_accuracy: 0.9718  
Epoch 50/50  
82/82 [=====] - 4s 55ms/step - loss: 5.5277e-05 - accuracy: 1.0000 - val\_loss: 0.2112 - val\_accuracy: 0.9718  
21/21 [=====] - 0s 8ms/step - loss: 0.3306 - accuracy: 0.9527  
Epoch 1/50  
82/82 [=====] - 5s 55ms/step - loss: 0.5559 - accuracy: 0.7447 - val\_loss: 0.3439 - val\_accuracy: 0.8640  
Epoch 2/50  
82/82 [=====] - 4s 54ms/step - loss: 0.3072 - accuracy: 0.8628 - val\_loss: 0.2442 - val\_accuracy: 0.8909  
Epoch 3/50  
82/82 [=====] - 4s 53ms/step - loss: 0.2207 - accuracy: 0.9113 - val\_loss: 0.1788 - val\_accuracy: 0.9314  
Epoch 4/50  
82/82 [=====] - 4s 55ms/step - loss: 0.1696 - accuracy: 0.9354 - val\_loss: 0.1606 - val\_accuracy: 0.9436  
Epoch 5/50  
82/82 [=====] - 4s 52ms/step - loss: 0.1654 - accuracy: 0.9358 - val\_loss: 0.1204 - val\_accuracy: 0.9571  
Epoch 6/50

82/82 [=====] - 4s 54ms/step - loss: 0.1251 - accuracy: 0.9496 - val\_loss: 0.1042 - val\_accuracy: 0.9645  
Epoch 7/50  
82/82 [=====] - 4s 53ms/step - loss: 0.1127 - accuracy: 0.9580 - val\_loss: 0.1326 - val\_accuracy: 0.9522  
Epoch 8/50  
82/82 [=====] - 5s 56ms/step - loss: 0.1010 - accuracy: 0.9618 - val\_loss: 0.1574 - val\_accuracy: 0.9400  
Epoch 9/50  
82/82 [=====] - 4s 51ms/step - loss: 0.1111 - accuracy: 0.9572 - val\_loss: 0.0952 - val\_accuracy: 0.9645  
Epoch 10/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0950 - accuracy: 0.9633 - val\_loss: 0.0869 - val\_accuracy: 0.9706  
Epoch 11/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0713 - accuracy: 0.9744 - val\_loss: 0.0858 - val\_accuracy: 0.9657  
Epoch 12/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0695 - accuracy: 0.9710 - val\_loss: 0.0991 - val\_accuracy: 0.9657  
Epoch 13/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0623 - accuracy: 0.9778 - val\_loss: 0.0964 - val\_accuracy: 0.9694  
Epoch 14/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0500 - accuracy: 0.9824 - val\_loss: 0.0826 - val\_accuracy: 0.9694  
Epoch 15/50  
82/82 [=====] - 5s 55ms/step - loss: 0.0663 - accuracy: 0.9767 - val\_loss: 0.1003 - val\_accuracy: 0.9645  
Epoch 16/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0541 - accuracy: 0.9786 - val\_loss: 0.1066 - val\_accuracy: 0.9694  
Epoch 17/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0370 - accuracy: 0.9882 - val\_loss: 0.1027 - val\_accuracy: 0.9718  
Epoch 18/50  
82/82 [=====] - 6s 68ms/step - loss: 0.0275 - accuracy: 0.9927 - val\_loss: 0.1109 - val\_accuracy: 0.9681  
Epoch 19/50  
82/82 [=====] - 6s 69ms/step - loss: 0.0197 - accuracy: 0.9962 - val\_loss: 0.1534 - val\_accuracy: 0.9608  
Epoch 20/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0193 - accuracy: 0.9943 - val\_loss: 0.1249 - val\_accuracy: 0.9694  
Epoch 21/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0269 - accuracy: 0.9901 - val\_loss: 0.1573 - val\_accuracy: 0.9583  
Epoch 22/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0273 - accuracy: 0.9893 - val\_loss: 0.1364 - val\_accuracy: 0.9608  
Epoch 23/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0131 - accuracy: 0.9969 - val\_loss: 0.1230 - val\_accuracy: 0.9694  
Epoch 24/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0111 - accuracy: 0.9973 - val\_loss: 0.1257 - val\_accuracy: 0.9718

Epoch 25/50  
82/82 [=====] - 5s 55ms/step - loss: 0.0062 - accuracy: 0.9992 - val\_loss: 0.1208 - val\_accuracy: 0.9681  
Epoch 26/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0037 - accuracy: 0.9992 - val\_loss: 0.1727 - val\_accuracy: 0.9669  
Epoch 27/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0014 - accuracy: 1.0000 - val\_loss: 0.1499 - val\_accuracy: 0.9694  
Epoch 28/50  
82/82 [=====] - 4s 52ms/step - loss: 7.6304e-04 - accuracy: 1.0000 - val\_loss: 0.1720 - val\_accuracy: 0.9681  
Epoch 29/50  
82/82 [=====] - 4s 53ms/step - loss: 6.2447e-04 - accuracy: 1.0000 - val\_loss: 0.1570 - val\_accuracy: 0.9669  
Epoch 30/50  
82/82 [=====] - 5s 55ms/step - loss: 3.7851e-04 - accuracy: 1.0000 - val\_loss: 0.1624 - val\_accuracy: 0.9669  
Epoch 31/50  
82/82 [=====] - 4s 54ms/step - loss: 3.2356e-04 - accuracy: 1.0000 - val\_loss: 0.1648 - val\_accuracy: 0.9657  
Epoch 32/50  
82/82 [=====] - 5s 59ms/step - loss: 2.8068e-04 - accuracy: 1.0000 - val\_loss: 0.1680 - val\_accuracy: 0.9669  
Epoch 33/50  
82/82 [=====] - 5s 55ms/step - loss: 2.4862e-04 - accuracy: 1.0000 - val\_loss: 0.1680 - val\_accuracy: 0.9694  
Epoch 34/50  
82/82 [=====] - 4s 54ms/step - loss: 2.2027e-04 - accuracy: 1.0000 - val\_loss: 0.1718 - val\_accuracy: 0.9681  
Epoch 35/50  
82/82 [=====] - 5s 57ms/step - loss: 1.9212e-04 - accuracy: 1.0000 - val\_loss: 0.1732 - val\_accuracy: 0.9669  
Epoch 36/50  
82/82 [=====] - 4s 55ms/step - loss: 1.7356e-04 - accuracy: 1.0000 - val\_loss: 0.1752 - val\_accuracy: 0.9657  
Epoch 37/50  
82/82 [=====] - 4s 53ms/step - loss: 1.5820e-04 - accuracy: 1.0000 - val\_loss: 0.1767 - val\_accuracy: 0.9669  
Epoch 38/50  
82/82 [=====] - 4s 54ms/step - loss: 1.4719e-04 - accuracy: 1.0000 - val\_loss: 0.1806 - val\_accuracy: 0.9669  
Epoch 39/50  
82/82 [=====] - 4s 53ms/step - loss: 1.3646e-04 - accuracy: 1.0000 - val\_loss: 0.1810 - val\_accuracy: 0.9657  
Epoch 40/50  
82/82 [=====] - 5s 60ms/step - loss: 1.2460e-04 - accuracy: 1.0000 - val\_loss: 0.1815 - val\_accuracy: 0.9657  
Epoch 41/50  
82/82 [=====] - 4s 54ms/step - loss: 1.1052e-04 - accuracy: 1.0000 - val\_loss: 0.1836 - val\_accuracy: 0.9657  
Epoch 42/50  
82/82 [=====] - 4s 54ms/step - loss: 1.0307e-04 - accuracy: 1.0000 - val\_loss: 0.1851 - val\_accuracy: 0.9657  
Epoch 43/50  
82/82 [=====] - 4s 53ms/step - loss: 9.7054e-05 -

accuracy: 1.0000 - val\_loss: 0.1852 - val\_accuracy: 0.9681  
Epoch 44/50  
82/82 [=====] - 4s 54ms/step - loss: 8.9348e-05 -  
accuracy: 1.0000 - val\_loss: 0.1881 - val\_accuracy: 0.9657  
Epoch 45/50  
82/82 [=====] - 4s 53ms/step - loss: 8.0773e-05 -  
accuracy: 1.0000 - val\_loss: 0.1889 - val\_accuracy: 0.9657  
Epoch 46/50  
82/82 [=====] - 4s 52ms/step - loss: 7.8911e-05 -  
accuracy: 1.0000 - val\_loss: 0.1895 - val\_accuracy: 0.9657  
Epoch 47/50  
82/82 [=====] - 5s 56ms/step - loss: 7.0959e-05 -  
accuracy: 1.0000 - val\_loss: 0.1926 - val\_accuracy: 0.9657  
Epoch 48/50  
82/82 [=====] - 4s 54ms/step - loss: 6.8111e-05 -  
accuracy: 1.0000 - val\_loss: 0.1945 - val\_accuracy: 0.9681  
Epoch 49/50  
82/82 [=====] - 5s 56ms/step - loss: 6.0173e-05 -  
accuracy: 1.0000 - val\_loss: 0.1944 - val\_accuracy: 0.9657  
Epoch 50/50  
82/82 [=====] - 4s 52ms/step - loss: 5.6410e-05 -  
accuracy: 1.0000 - val\_loss: 0.1969 - val\_accuracy: 0.9681  
21/21 [=====] - 0s 8ms/step - loss: 0.2163 - accu  
acy: 0.9557  
Epoch 1/50  
82/82 [=====] - 5s 58ms/step - loss: 0.5806 - accu  
racy: 0.7299 - val\_loss: 0.4376 - val\_accuracy: 0.7659  
Epoch 2/50  
82/82 [=====] - 5s 57ms/step - loss: 0.2998 - accu  
racy: 0.8724 - val\_loss: 0.2044 - val\_accuracy: 0.9093  
Epoch 3/50  
82/82 [=====] - 4s 54ms/step - loss: 0.2444 - accu  
racy: 0.8942 - val\_loss: 0.2229 - val\_accuracy: 0.9032  
Epoch 4/50  
82/82 [=====] - 4s 53ms/step - loss: 0.1961 - accu  
racy: 0.9225 - val\_loss: 0.1542 - val\_accuracy: 0.9424  
Epoch 5/50  
82/82 [=====] - 4s 51ms/step - loss: 0.1719 - accu  
racy: 0.9358 - val\_loss: 0.1459 - val\_accuracy: 0.9522  
Epoch 6/50  
82/82 [=====] - 5s 55ms/step - loss: 0.1561 - accu  
racy: 0.9465 - val\_loss: 0.1485 - val\_accuracy: 0.9473  
Epoch 7/50  
82/82 [=====] - 4s 51ms/step - loss: 0.1368 - accu  
racy: 0.9481 - val\_loss: 0.1175 - val\_accuracy: 0.9571  
Epoch 8/50  
82/82 [=====] - 5s 56ms/step - loss: 0.1183 - accu  
racy: 0.9595 - val\_loss: 0.1076 - val\_accuracy: 0.9559  
Epoch 9/50  
82/82 [=====] - 4s 54ms/step - loss: 0.1178 - accu  
racy: 0.9637 - val\_loss: 0.1340 - val\_accuracy: 0.9583  
Epoch 10/50  
82/82 [=====] - 5s 56ms/step - loss: 0.1039 - accu  
racy: 0.9645 - val\_loss: 0.1025 - val\_accuracy: 0.9620  
Epoch 11/50  
82/82 [=====] - 5s 55ms/step - loss: 0.1135 - accu

racy: 0.9637 - val\_loss: 0.1003 - val\_accuracy: 0.9632  
Epoch 12/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0949 - accu  
racy: 0.9672 - val\_loss: 0.0936 - val\_accuracy: 0.9657  
Epoch 13/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0877 - accu  
racy: 0.9675 - val\_loss: 0.1030 - val\_accuracy: 0.9645  
Epoch 14/50  
82/82 [=====] - 4s 55ms/step - loss: 0.0783 - accu  
racy: 0.9694 - val\_loss: 0.1157 - val\_accuracy: 0.9657  
Epoch 15/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0802 - accu  
racy: 0.9721 - val\_loss: 0.1027 - val\_accuracy: 0.9620  
Epoch 16/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0802 - accu  
racy: 0.9725 - val\_loss: 0.0996 - val\_accuracy: 0.9681  
Epoch 17/50  
82/82 [=====] - 4s 55ms/step - loss: 0.0668 - accu  
racy: 0.9744 - val\_loss: 0.0938 - val\_accuracy: 0.9718  
Epoch 18/50  
82/82 [=====] - 4s 51ms/step - loss: 0.0564 - accu  
racy: 0.9798 - val\_loss: 0.1272 - val\_accuracy: 0.9620  
Epoch 19/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0507 - accu  
racy: 0.9847 - val\_loss: 0.0995 - val\_accuracy: 0.9657  
Epoch 20/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0455 - accu  
racy: 0.9847 - val\_loss: 0.0994 - val\_accuracy: 0.9657  
Epoch 21/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0391 - accu  
racy: 0.9862 - val\_loss: 0.0997 - val\_accuracy: 0.9694  
Epoch 22/50  
82/82 [=====] - 4s 55ms/step - loss: 0.0274 - accu  
racy: 0.9924 - val\_loss: 0.0996 - val\_accuracy: 0.9681  
Epoch 23/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0275 - accu  
racy: 0.9912 - val\_loss: 0.1065 - val\_accuracy: 0.9632  
Epoch 24/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0426 - accu  
racy: 0.9847 - val\_loss: 0.1128 - val\_accuracy: 0.9694  
Epoch 25/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0403 - accu  
racy: 0.9832 - val\_loss: 0.1437 - val\_accuracy: 0.9632  
Epoch 26/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0150 - accu  
racy: 0.9962 - val\_loss: 0.1226 - val\_accuracy: 0.9669  
Epoch 27/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0079 - accu  
racy: 0.9985 - val\_loss: 0.1341 - val\_accuracy: 0.9681  
Epoch 28/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0045 - accu  
racy: 0.9989 - val\_loss: 0.1366 - val\_accuracy: 0.9669  
Epoch 29/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0026 - accu  
racy: 1.0000 - val\_loss: 0.1355 - val\_accuracy: 0.9694  
Epoch 30/50

82/82 [=====] - 5s 55ms/step - loss: 0.0019 - accuracy: 1.0000 - val\_loss: 0.1364 - val\_accuracy: 0.9669  
Epoch 31/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0012 - accuracy: 1.0000 - val\_loss: 0.1416 - val\_accuracy: 0.9694  
Epoch 32/50  
82/82 [=====] - 5s 56ms/step - loss: 8.9202e-04 - accuracy: 1.0000 - val\_loss: 0.1474 - val\_accuracy: 0.9669  
Epoch 33/50  
82/82 [=====] - 5s 57ms/step - loss: 7.4399e-04 - accuracy: 1.0000 - val\_loss: 0.1467 - val\_accuracy: 0.9669  
Epoch 34/50  
82/82 [=====] - 4s 52ms/step - loss: 6.0491e-04 - accuracy: 1.0000 - val\_loss: 0.1565 - val\_accuracy: 0.9657  
Epoch 35/50  
82/82 [=====] - 5s 55ms/step - loss: 5.1582e-04 - accuracy: 1.0000 - val\_loss: 0.1542 - val\_accuracy: 0.9681  
Epoch 36/50  
82/82 [=====] - 4s 55ms/step - loss: 4.5817e-04 - accuracy: 1.0000 - val\_loss: 0.1597 - val\_accuracy: 0.9694  
Epoch 37/50  
82/82 [=====] - 5s 56ms/step - loss: 4.0352e-04 - accuracy: 1.0000 - val\_loss: 0.1626 - val\_accuracy: 0.9657  
Epoch 38/50  
82/82 [=====] - 4s 54ms/step - loss: 3.3340e-04 - accuracy: 1.0000 - val\_loss: 0.1694 - val\_accuracy: 0.9657  
Epoch 39/50  
82/82 [=====] - 4s 54ms/step - loss: 3.0037e-04 - accuracy: 1.0000 - val\_loss: 0.1682 - val\_accuracy: 0.9657  
Epoch 40/50  
82/82 [=====] - 4s 55ms/step - loss: 2.7357e-04 - accuracy: 1.0000 - val\_loss: 0.1702 - val\_accuracy: 0.9681  
Epoch 41/50  
82/82 [=====] - 4s 54ms/step - loss: 2.3893e-04 - accuracy: 1.0000 - val\_loss: 0.1733 - val\_accuracy: 0.9669  
Epoch 42/50  
82/82 [=====] - 5s 56ms/step - loss: 2.2081e-04 - accuracy: 1.0000 - val\_loss: 0.1754 - val\_accuracy: 0.9681  
Epoch 43/50  
82/82 [=====] - 4s 54ms/step - loss: 2.0328e-04 - accuracy: 1.0000 - val\_loss: 0.1781 - val\_accuracy: 0.9669  
Epoch 44/50  
82/82 [=====] - 4s 53ms/step - loss: 1.8055e-04 - accuracy: 1.0000 - val\_loss: 0.1798 - val\_accuracy: 0.9669  
Epoch 45/50  
82/82 [=====] - 4s 54ms/step - loss: 1.6609e-04 - accuracy: 1.0000 - val\_loss: 0.1806 - val\_accuracy: 0.9681  
Epoch 46/50  
82/82 [=====] - 4s 51ms/step - loss: 1.5097e-04 - accuracy: 1.0000 - val\_loss: 0.1843 - val\_accuracy: 0.9657  
Epoch 47/50  
82/82 [=====] - 5s 56ms/step - loss: 1.4085e-04 - accuracy: 1.0000 - val\_loss: 0.1870 - val\_accuracy: 0.9657  
Epoch 48/50  
82/82 [=====] - 4s 53ms/step - loss: 1.2340e-04 - accuracy: 1.0000 - val\_loss: 0.1889 - val\_accuracy: 0.9657

Epoch 49/50  
82/82 [=====] - 4s 54ms/step - loss: 1.1453e-04 - accuracy: 1.0000 - val\_loss: 0.1897 - val\_accuracy: 0.9669  
Epoch 50/50  
82/82 [=====] - 4s 55ms/step - loss: 1.0371e-04 - accuracy: 1.0000 - val\_loss: 0.1928 - val\_accuracy: 0.9657  
21/21 [=====] - 0s 8ms/step - loss: 0.2621 - accuracy: 0.9602  
Epoch 1/50  
82/82 [=====] - 5s 57ms/step - loss: 0.5262 - accuracy: 0.7552 - val\_loss: 0.3385 - val\_accuracy: 0.8860  
Epoch 2/50  
82/82 [=====] - 4s 53ms/step - loss: 0.2515 - accuracy: 0.8946 - val\_loss: 0.1743 - val\_accuracy: 0.9301  
Epoch 3/50  
82/82 [=====] - 4s 51ms/step - loss: 0.1779 - accuracy: 0.9282 - val\_loss: 0.1529 - val\_accuracy: 0.9485  
Epoch 4/50  
82/82 [=====] - 4s 52ms/step - loss: 0.1486 - accuracy: 0.9412 - val\_loss: 0.1253 - val\_accuracy: 0.9632  
Epoch 5/50  
82/82 [=====] - 4s 54ms/step - loss: 0.1259 - accuracy: 0.9511 - val\_loss: 0.1501 - val\_accuracy: 0.9547  
Epoch 6/50  
82/82 [=====] - 4s 54ms/step - loss: 0.1089 - accuracy: 0.9629 - val\_loss: 0.1038 - val\_accuracy: 0.9657  
Epoch 7/50  
82/82 [=====] - 4s 51ms/step - loss: 0.1037 - accuracy: 0.9580 - val\_loss: 0.1320 - val\_accuracy: 0.9510  
Epoch 8/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0892 - accuracy: 0.9710 - val\_loss: 0.1029 - val\_accuracy: 0.9632  
Epoch 9/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0937 - accuracy: 0.9641 - val\_loss: 0.1038 - val\_accuracy: 0.9669  
Epoch 10/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0796 - accuracy: 0.9706 - val\_loss: 0.0958 - val\_accuracy: 0.9620  
Epoch 11/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0721 - accuracy: 0.9721 - val\_loss: 0.0879 - val\_accuracy: 0.9718  
Epoch 12/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0695 - accuracy: 0.9740 - val\_loss: 0.1033 - val\_accuracy: 0.9645  
Epoch 13/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0637 - accuracy: 0.9786 - val\_loss: 0.1121 - val\_accuracy: 0.9596  
Epoch 14/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0570 - accuracy: 0.9778 - val\_loss: 0.1633 - val\_accuracy: 0.9534  
Epoch 15/50  
82/82 [=====] - 4s 51ms/step - loss: 0.0478 - accuracy: 0.9824 - val\_loss: 0.0977 - val\_accuracy: 0.9681  
Epoch 16/50  
82/82 [=====] - 4s 50ms/step - loss: 0.0360 - accuracy: 0.9885 - val\_loss: 0.0942 - val\_accuracy: 0.9718

Epoch 17/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0480 - accuracy: 0.9817 - val\_loss: 0.0944 - val\_accuracy: 0.9681  
Epoch 18/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0397 - accuracy: 0.9874 - val\_loss: 0.1076 - val\_accuracy: 0.9681  
Epoch 19/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0266 - accuracy: 0.9916 - val\_loss: 0.1051 - val\_accuracy: 0.9730  
Epoch 20/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0250 - accuracy: 0.9924 - val\_loss: 0.1206 - val\_accuracy: 0.9694  
Epoch 21/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0246 - accuracy: 0.9908 - val\_loss: 0.1194 - val\_accuracy: 0.9669  
Epoch 22/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0176 - accuracy: 0.9947 - val\_loss: 0.1417 - val\_accuracy: 0.9669  
Epoch 23/50  
82/82 [=====] - 4s 51ms/step - loss: 0.0259 - accuracy: 0.9901 - val\_loss: 0.1115 - val\_accuracy: 0.9706  
Epoch 24/50  
82/82 [=====] - 4s 51ms/step - loss: 0.0169 - accuracy: 0.9935 - val\_loss: 0.1357 - val\_accuracy: 0.9718  
Epoch 25/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0148 - accuracy: 0.9939 - val\_loss: 0.1378 - val\_accuracy: 0.9718  
Epoch 26/50  
82/82 [=====] - 4s 55ms/step - loss: 0.0035 - accuracy: 0.9996 - val\_loss: 0.1447 - val\_accuracy: 0.9669  
Epoch 27/50  
82/82 [=====] - 4s 55ms/step - loss: 0.0022 - accuracy: 0.9996 - val\_loss: 0.1580 - val\_accuracy: 0.9706  
Epoch 28/50  
82/82 [=====] - 5s 57ms/step - loss: 8.6739e-04 - accuracy: 1.0000 - val\_loss: 0.1648 - val\_accuracy: 0.9694  
Epoch 29/50  
82/82 [=====] - 4s 51ms/step - loss: 6.0034e-04 - accuracy: 1.0000 - val\_loss: 0.1686 - val\_accuracy: 0.9706  
Epoch 30/50  
82/82 [=====] - 4s 54ms/step - loss: 3.7772e-04 - accuracy: 1.0000 - val\_loss: 0.1710 - val\_accuracy: 0.9706  
Epoch 31/50  
82/82 [=====] - 4s 53ms/step - loss: 3.0104e-04 - accuracy: 1.0000 - val\_loss: 0.1730 - val\_accuracy: 0.9694  
Epoch 32/50  
82/82 [=====] - 4s 54ms/step - loss: 2.4041e-04 - accuracy: 1.0000 - val\_loss: 0.1761 - val\_accuracy: 0.9681  
Epoch 33/50  
82/82 [=====] - 4s 51ms/step - loss: 2.1004e-04 - accuracy: 1.0000 - val\_loss: 0.1776 - val\_accuracy: 0.9681  
Epoch 34/50  
82/82 [=====] - 4s 54ms/step - loss: 1.8199e-04 - accuracy: 1.0000 - val\_loss: 0.1819 - val\_accuracy: 0.9706  
Epoch 35/50  
82/82 [=====] - 4s 49ms/step - loss: 1.7595e-04 -



accuracy: 1.0000 - val\_loss: 0.1828 - val\_accuracy: 0.9694  
Epoch 36/50  
82/82 [=====] - 4s 52ms/step - loss: 1.4969e-04 -  
accuracy: 1.0000 - val\_loss: 0.1847 - val\_accuracy: 0.9694  
Epoch 37/50  
82/82 [=====] - 4s 53ms/step - loss: 1.3258e-04 -  
accuracy: 1.0000 - val\_loss: 0.1862 - val\_accuracy: 0.9694  
Epoch 38/50  
82/82 [=====] - 4s 54ms/step - loss: 1.2066e-04 -  
accuracy: 1.0000 - val\_loss: 0.1880 - val\_accuracy: 0.9694  
Epoch 39/50  
82/82 [=====] - 4s 54ms/step - loss: 1.1062e-04 -  
accuracy: 1.0000 - val\_loss: 0.1909 - val\_accuracy: 0.9706  
Epoch 40/50  
82/82 [=====] - 4s 53ms/step - loss: 1.0589e-04 -  
accuracy: 1.0000 - val\_loss: 0.1926 - val\_accuracy: 0.9694  
Epoch 41/50  
82/82 [=====] - 4s 54ms/step - loss: 9.5854e-05 -  
accuracy: 1.0000 - val\_loss: 0.1932 - val\_accuracy: 0.9694  
Epoch 42/50  
82/82 [=====] - 4s 53ms/step - loss: 8.8463e-05 -  
accuracy: 1.0000 - val\_loss: 0.1963 - val\_accuracy: 0.9706  
Epoch 43/50  
82/82 [=====] - 4s 54ms/step - loss: 8.2568e-05 -  
accuracy: 1.0000 - val\_loss: 0.1963 - val\_accuracy: 0.9694  
Epoch 44/50  
82/82 [=====] - 5s 55ms/step - loss: 7.6453e-05 -  
accuracy: 1.0000 - val\_loss: 0.1984 - val\_accuracy: 0.9694  
Epoch 45/50  
82/82 [=====] - 4s 51ms/step - loss: 7.4079e-05 -  
accuracy: 1.0000 - val\_loss: 0.1999 - val\_accuracy: 0.9694  
Epoch 46/50  
82/82 [=====] - 4s 53ms/step - loss: 6.3901e-05 -  
accuracy: 1.0000 - val\_loss: 0.2009 - val\_accuracy: 0.9681  
Epoch 47/50  
82/82 [=====] - 5s 55ms/step - loss: 6.2029e-05 -  
accuracy: 1.0000 - val\_loss: 0.2018 - val\_accuracy: 0.9694  
Epoch 48/50  
82/82 [=====] - 4s 52ms/step - loss: 5.6840e-05 -  
accuracy: 1.0000 - val\_loss: 0.2037 - val\_accuracy: 0.9694  
Epoch 49/50  
82/82 [=====] - 4s 53ms/step - loss: 5.2199e-05 -  
accuracy: 1.0000 - val\_loss: 0.2051 - val\_accuracy: 0.9694  
Epoch 50/50  
82/82 [=====] - 4s 51ms/step - loss: 4.8823e-05 -  
accuracy: 1.0000 - val\_loss: 0.2062 - val\_accuracy: 0.9681  
21/21 [=====] - 0s 8ms/step - loss: 0.3448 - accu  
acy: 0.9526  
Epoch 1/50  
82/82 [=====] - 5s 56ms/step - loss: 0.5190 - accu  
racy: 0.7605 - val\_loss: 0.2637 - val\_accuracy: 0.8885  
Epoch 2/50  
82/82 [=====] - 4s 52ms/step - loss: 0.2374 - accu  
racy: 0.9026 - val\_loss: 0.1764 - val\_accuracy: 0.9363  
Epoch 3/50  
82/82 [=====] - 5s 60ms/step - loss: 0.1851 - accu

racy: 0.9324 - val\_loss: 0.1560 - val\_accuracy: 0.9534  
Epoch 4/50  
82/82 [=====] - 4s 51ms/step - loss: 0.1519 - accu  
racy: 0.9435 - val\_loss: 0.1147 - val\_accuracy: 0.9632  
Epoch 5/50  
82/82 [=====] - 5s 56ms/step - loss: 0.1518 - accu  
racy: 0.9481 - val\_loss: 0.1142 - val\_accuracy: 0.9608  
Epoch 6/50  
82/82 [=====] - 4s 53ms/step - loss: 0.1264 - accu  
racy: 0.9538 - val\_loss: 0.1017 - val\_accuracy: 0.9694  
Epoch 7/50  
82/82 [=====] - 4s 53ms/step - loss: 0.1161 - accu  
racy: 0.9584 - val\_loss: 0.1216 - val\_accuracy: 0.9534  
Epoch 8/50  
82/82 [=====] - 4s 54ms/step - loss: 0.1176 - accu  
racy: 0.9580 - val\_loss: 0.1061 - val\_accuracy: 0.9669  
Epoch 9/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0938 - accu  
racy: 0.9645 - val\_loss: 0.1046 - val\_accuracy: 0.9694  
Epoch 10/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0886 - accu  
racy: 0.9687 - val\_loss: 0.1207 - val\_accuracy: 0.9645  
Epoch 11/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0915 - accu  
racy: 0.9710 - val\_loss: 0.1062 - val\_accuracy: 0.9681  
Epoch 12/50  
82/82 [=====] - 4s 51ms/step - loss: 0.0779 - accu  
racy: 0.9706 - val\_loss: 0.1417 - val\_accuracy: 0.9632  
Epoch 13/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0700 - accu  
racy: 0.9767 - val\_loss: 0.0994 - val\_accuracy: 0.9694  
Epoch 14/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0597 - accu  
racy: 0.9775 - val\_loss: 0.1006 - val\_accuracy: 0.9645  
Epoch 15/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0471 - accu  
racy: 0.9824 - val\_loss: 0.1048 - val\_accuracy: 0.9669  
Epoch 16/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0509 - accu  
racy: 0.9824 - val\_loss: 0.1355 - val\_accuracy: 0.9559  
Epoch 17/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0362 - accu  
racy: 0.9897 - val\_loss: 0.1149 - val\_accuracy: 0.9645  
Epoch 18/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0298 - accu  
racy: 0.9901 - val\_loss: 0.1791 - val\_accuracy: 0.9559  
Epoch 19/50  
82/82 [=====] - 5s 55ms/step - loss: 0.0293 - accu  
racy: 0.9882 - val\_loss: 0.1162 - val\_accuracy: 0.9657  
Epoch 20/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0214 - accu  
racy: 0.9947 - val\_loss: 0.1120 - val\_accuracy: 0.9669  
Epoch 21/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0190 - accu  
racy: 0.9947 - val\_loss: 0.1360 - val\_accuracy: 0.9657  
Epoch 22/50

82/82 [=====] - 4s 55ms/step - loss: 0.0239 - accuracy: 0.9908 - val\_loss: 0.1500 - val\_accuracy: 0.9669  
Epoch 23/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0091 - accuracy: 0.9981 - val\_loss: 0.1569 - val\_accuracy: 0.9645  
Epoch 24/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0151 - accuracy: 0.9943 - val\_loss: 0.1546 - val\_accuracy: 0.9669  
Epoch 25/50  
82/82 [=====] - 4s 55ms/step - loss: 0.0068 - accuracy: 0.9985 - val\_loss: 0.1550 - val\_accuracy: 0.9681  
Epoch 26/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0021 - accuracy: 1.0000 - val\_loss: 0.1702 - val\_accuracy: 0.9669  
Epoch 27/50  
82/82 [=====] - 5s 55ms/step - loss: 8.3900e-04 - accuracy: 1.0000 - val\_loss: 0.1807 - val\_accuracy: 0.9657  
Epoch 28/50  
82/82 [=====] - 5s 56ms/step - loss: 5.3911e-04 - accuracy: 1.0000 - val\_loss: 0.1757 - val\_accuracy: 0.9681  
Epoch 29/50  
82/82 [=====] - 4s 54ms/step - loss: 3.9854e-04 - accuracy: 1.0000 - val\_loss: 0.1817 - val\_accuracy: 0.9669  
Epoch 30/50  
82/82 [=====] - 4s 53ms/step - loss: 3.1498e-04 - accuracy: 1.0000 - val\_loss: 0.1820 - val\_accuracy: 0.9681  
Epoch 31/50  
82/82 [=====] - 5s 55ms/step - loss: 2.8346e-04 - accuracy: 1.0000 - val\_loss: 0.1875 - val\_accuracy: 0.9681  
Epoch 32/50  
82/82 [=====] - 4s 51ms/step - loss: 2.4608e-04 - accuracy: 1.0000 - val\_loss: 0.1891 - val\_accuracy: 0.9681  
Epoch 33/50  
82/82 [=====] - 5s 57ms/step - loss: 2.1484e-04 - accuracy: 1.0000 - val\_loss: 0.1927 - val\_accuracy: 0.9681  
Epoch 34/50  
82/82 [=====] - 5s 57ms/step - loss: 1.9364e-04 - accuracy: 1.0000 - val\_loss: 0.1952 - val\_accuracy: 0.9681  
Epoch 35/50  
82/82 [=====] - 4s 52ms/step - loss: 1.6972e-04 - accuracy: 1.0000 - val\_loss: 0.2016 - val\_accuracy: 0.9657  
Epoch 36/50  
82/82 [=====] - 4s 54ms/step - loss: 1.6197e-04 - accuracy: 1.0000 - val\_loss: 0.1975 - val\_accuracy: 0.9681  
Epoch 37/50  
82/82 [=====] - 4s 54ms/step - loss: 1.4088e-04 - accuracy: 1.0000 - val\_loss: 0.2035 - val\_accuracy: 0.9669  
Epoch 38/50  
82/82 [=====] - 5s 55ms/step - loss: 1.3229e-04 - accuracy: 1.0000 - val\_loss: 0.2037 - val\_accuracy: 0.9681  
Epoch 39/50  
82/82 [=====] - 5s 57ms/step - loss: 1.1834e-04 - accuracy: 1.0000 - val\_loss: 0.2037 - val\_accuracy: 0.9694  
Epoch 40/50  
82/82 [=====] - 5s 58ms/step - loss: 1.0972e-04 - accuracy: 1.0000 - val\_loss: 0.2086 - val\_accuracy: 0.9669

```

Epoch 41/50
82/82 [=====] - 5s 57ms/step - loss: 1.0043e-04 -
accuracy: 1.0000 - val_loss: 0.2084 - val_accuracy: 0.9694
Epoch 42/50
82/82 [=====] - 5s 56ms/step - loss: 9.0478e-05 -
accuracy: 1.0000 - val_loss: 0.2140 - val_accuracy: 0.9669
Epoch 43/50
82/82 [=====] - 5s 55ms/step - loss: 8.8168e-05 -
accuracy: 1.0000 - val_loss: 0.2128 - val_accuracy: 0.9694
Epoch 44/50
82/82 [=====] - 4s 53ms/step - loss: 7.9163e-05 -
accuracy: 1.0000 - val_loss: 0.2131 - val_accuracy: 0.9694
Epoch 45/50
82/82 [=====] - 5s 58ms/step - loss: 7.3592e-05 -
accuracy: 1.0000 - val_loss: 0.2158 - val_accuracy: 0.9694
Epoch 46/50
82/82 [=====] - 4s 55ms/step - loss: 7.0926e-05 -
accuracy: 1.0000 - val_loss: 0.2186 - val_accuracy: 0.9694
Epoch 47/50
82/82 [=====] - 4s 53ms/step - loss: 6.2789e-05 -
accuracy: 1.0000 - val_loss: 0.2195 - val_accuracy: 0.9694
Epoch 48/50
82/82 [=====] - 4s 53ms/step - loss: 5.9645e-05 -
accuracy: 1.0000 - val_loss: 0.2238 - val_accuracy: 0.9681
Epoch 49/50
82/82 [=====] - 4s 53ms/step - loss: 5.5517e-05 -
accuracy: 1.0000 - val_loss: 0.2233 - val_accuracy: 0.9694

```

```
In [62]: save_result('CNN #2', results_train[1], results_test[1], cvs[0], cvs[1], cvs[2], cvs[3], cvs[4])
```

Out[62]:

	model_name	Train Accuracy	Test Accuracy	CV1	CV2	CV3	CV4	CV5	CV_Std	CV_avg
0	CNN #2	1.000	0.947	0.953	0.956	0.960	0.953	0.963	0.005	0.957
0	CNN #1	0.953	0.933	0.921	0.940	0.931	0.916	0.945	0.012	0.931
0	Initial Model	0.730	0.730	0.925	0.740	0.728	0.709	0.743	0.088	0.769

## Prediction for Confusion Matrix

```
In [63]: predictions = model2.predict(x = test_images, steps = 10, verbose=0)
```

```
In [64]: pred_check = np.round(predictions)
```

```
In [65]: pred_check = pred_check[:]
pred_check = pred_check.flatten()
pred_check
```

Out[65]: array([1., 1., 1., ..., 0., 0., 0.], dtype=float32)

```
In [66]: test_check = test_labels[:,0]
test_check
```

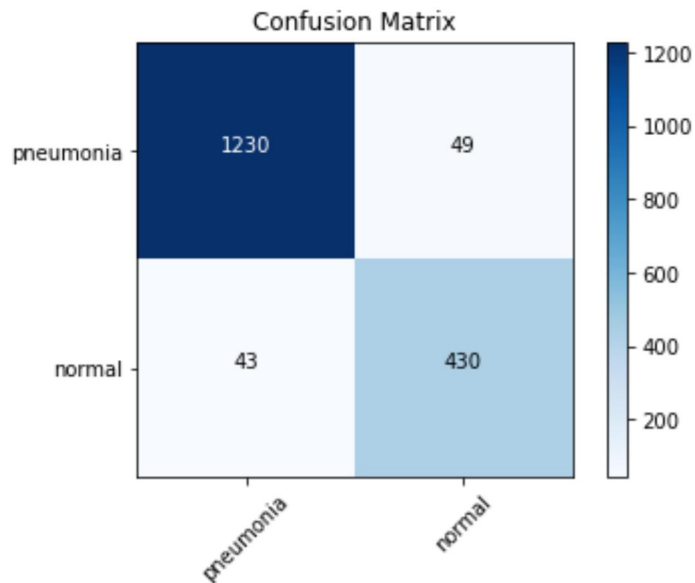
```
Out[66]: array([1., 1., 1., ..., 0., 0., 0.], dtype=float32)
```

```
In [67]: cm = confusion_matrix(y_true=test_check, y_pred=pred_check)
```

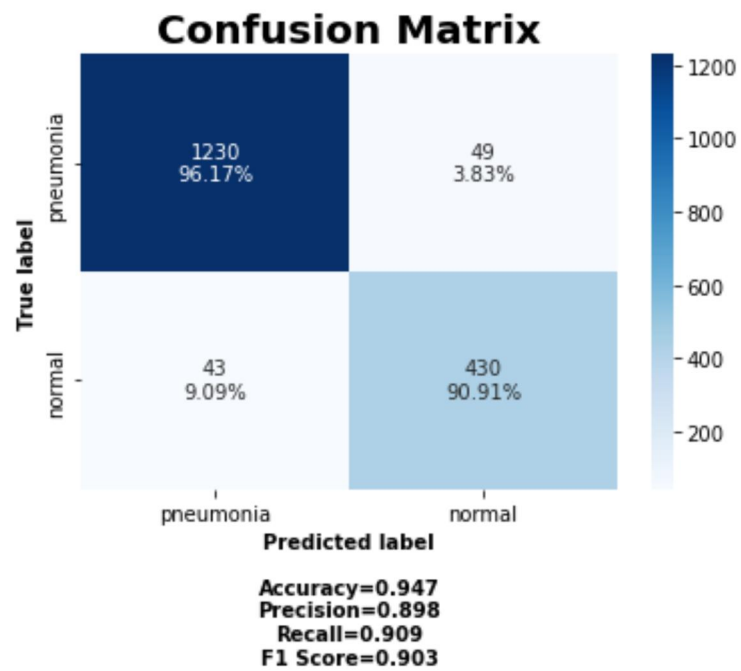
```
In [68]: cm_plot_labels = ['pneumonia', 'normal']
plot_confusion_matrix(cm=cm, classes=cm_plot_labels, title='Confusion Matrix')
```

Confusion matrix, without normalization

```
[[1230  49]
 [ 43 430]]
```



```
In [69]: cm_plot_labels = ['pneumonia', 'normal']  
make_confusion_matrix(cm, categories = cm_plot_labels, title='Confusion Matrix')
```



## CNN Model 3

For this model, I add two layers of batch normalization and a 10% dropout. Also added one more layer of Conv2D and MaxPooling.

```
In [70]: model 3 = models.Sequential()

model 3.add(layers.Conv2D(32, (3, 3), activation='relu', input_shape=(64, 64, 3)))
model 3.add(layers.MaxPooling2D((2, 2)))

model 3.add(layers.Conv2D(32, (4, 4), activation='relu'))
model 3.add(BatchNormalization())
model 3.add(layers.MaxPooling2D((2, 2)))

model 3.add(layers.Conv2D(64, (3, 3), activation='relu'))
model 3.add(layers.MaxPooling2D((2, 2)))

model 3.add(layers.Conv2D(128, (3, 3), activation='relu'))
model 3.add(BatchNormalization())
model 3.add(layers.MaxPooling2D((2, 2)))

model 3.add(layers.Flatten())
model 3.add(layers.Dense(64, activation='relu'))
model 3.add(Dropout(0.1))
model 3.add(layers.Dense(1, activation='sigmoid'))

model 3.compile(loss='binary_crossentropy',
                optimizer="adam",
                metrics=['accuracy'])
```

In [71]: model 3. summary()

Model: "sequential\_13"

Layer (type)	Output Shape	Param #
=====		
conv2d_42 (Conv2D)	(None, 62, 62, 32)	896
max_pooling2d_42 (MaxPooling)	(None, 31, 31, 32)	0
conv2d_43 (Conv2D)	(None, 28, 28, 32)	16416
batch_normalization (BatchNo	(None, 28, 28, 32)	128
max_pooling2d_43 (MaxPooling)	(None, 14, 14, 32)	0
conv2d_44 (Conv2D)	(None, 12, 12, 64)	18496
max_pooling2d_44 (MaxPooling)	(None, 6, 6, 64)	0
conv2d_45 (Conv2D)	(None, 4, 4, 128)	73856
batch_normalization_1 (Batch	(None, 4, 4, 128)	512
max_pooling2d_45 (MaxPooling)	(None, 2, 2, 128)	0
flatten_12 (Flatten)	(None, 512)	0
dense_48 (Dense)	(None, 64)	32832
dropout (Dropout)	(None, 64)	0
dense_49 (Dense)	(None, 1)	65
=====		
Total params: 143,201		
Trainable params: 142,881		
Non-trainable params: 320		

In [72]: print(f'train size {train\_size}, validation size {validation\_size}')

train size 3272, validation size 816



[illegible]

Epoch 1/50  
103/103 [=====] - 6s 58ms/step - loss: 0.2161 - accuracy: 0.9163 - val\_loss: 0.5187 - val\_accuracy: 0.7304

Epoch 2/50  
103/103 [=====] - 6s 60ms/step - loss: 0.1533 - accuracy: 0.9416 - val\_loss: 0.8475 - val\_accuracy: 0.3260

Epoch 3/50  
103/103 [=====] - 6s 59ms/step - loss: 0.1316 - accuracy: 0.9520 - val\_loss: 0.2674 - val\_accuracy: 0.9069

Epoch 4/50  
103/103 [=====] - 6s 59ms/step - loss: 0.1012 - accuracy: 0.9624 - val\_loss: 0.2688 - val\_accuracy: 0.8689

Epoch 5/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0890 - accuracy: 0.9685 - val\_loss: 0.2068 - val\_accuracy: 0.9412

Epoch 6/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0826 - accuracy: 0.9694 - val\_loss: 0.1537 - val\_accuracy: 0.9498

Epoch 7/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0706 - accuracy: 0.9746 - val\_loss: 0.2716 - val\_accuracy: 0.8860

Epoch 8/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0708 - accuracy: 0.9743 - val\_loss: 0.7441 - val\_accuracy: 0.8039

Epoch 9/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0629 - accuracy: 0.9786 - val\_loss: 0.1133 - val\_accuracy: 0.9706

Epoch 10/50  
103/103 [=====] - 6s 58ms/step - loss: 0.0462 - accuracy: 0.9838 - val\_loss: 0.1169 - val\_accuracy: 0.9583

Epoch 11/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0336 - accuracy: 0.9878 - val\_loss: 0.3937 - val\_accuracy: 0.8370

Epoch 12/50  
103/103 [=====] - 6s 59ms/step - loss: 0.0257 - accuracy: 0.9887 - val\_loss: 0.1195 - val\_accuracy: 0.9718

Epoch 13/50  
103/103 [=====] - 6s 55ms/step - loss: 0.0215 - accuracy: 0.9951 - val\_loss: 0.3163 - val\_accuracy: 0.9093

Epoch 14/50  
103/103 [=====] - 6s 60ms/step - loss: 0.0170 - accuracy: 0.9936 - val\_loss: 0.1578 - val\_accuracy: 0.9461

Epoch 15/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0282 - accuracy: 0.9908 - val\_loss: 0.4596 - val\_accuracy: 0.9056

Epoch 16/50  
103/103 [=====] - 6s 58ms/step - loss: 0.0211 - accuracy: 0.9911 - val\_loss: 0.1280 - val\_accuracy: 0.9669

Epoch 17/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0132 - accuracy: 0.9963 - val\_loss: 0.1360 - val\_accuracy: 0.9706

Epoch 18/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0037 - accuracy: 0.9991 - val\_loss: 0.1926 - val\_accuracy: 0.9522

Epoch 19/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0443 - ac

curacy: 0.9859 - val\_loss: 1.5699 - val\_accuracy: 0.7512  
Epoch 20/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0313 - ac  
curacy: 0.9890 - val\_loss: 1.4590 - val\_accuracy: 0.7574  
Epoch 21/50  
103/103 [=====] - 6s 61ms/step - loss: 0.0342 - ac  
curacy: 0.9872 - val\_loss: 2.1304 - val\_accuracy: 0.7672  
Epoch 22/50  
103/103 [=====] - 6s 55ms/step - loss: 0.0177 - ac  
curacy: 0.9927 - val\_loss: 0.6998 - val\_accuracy: 0.8713  
Epoch 23/50  
103/103 [=====] - 6s 60ms/step - loss: 0.0184 - ac  
curacy: 0.9924 - val\_loss: 1.1170 - val\_accuracy: 0.8431  
Epoch 24/50  
103/103 [=====] - 6s 59ms/step - loss: 0.0190 - ac  
curacy: 0.9936 - val\_loss: 0.1891 - val\_accuracy: 0.9608  
Epoch 25/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0028 - ac  
curacy: 0.9991 - val\_loss: 0.1723 - val\_accuracy: 0.9620  
Epoch 26/50  
103/103 [=====] - 6s 58ms/step - loss: 6.8374e-04  
- accuracy: 1.0000 - val\_loss: 0.1824 - val\_accuracy: 0.9681  
Epoch 27/50  
103/103 [=====] - 6s 57ms/step - loss: 3.5255e-04  
- accuracy: 1.0000 - val\_loss: 0.1908 - val\_accuracy: 0.9669  
Epoch 28/50  
103/103 [=====] - 6s 59ms/step - loss: 2.2159e-04  
- accuracy: 1.0000 - val\_loss: 0.1978 - val\_accuracy: 0.9669  
Epoch 29/50  
103/103 [=====] - 6s 58ms/step - loss: 1.1070e-04  
- accuracy: 1.0000 - val\_loss: 0.2038 - val\_accuracy: 0.9657  
Epoch 30/50  
103/103 [=====] - 6s 57ms/step - loss: 1.2790e-04  
- accuracy: 1.0000 - val\_loss: 0.2066 - val\_accuracy: 0.9657  
Epoch 31/50  
103/103 [=====] - 6s 55ms/step - loss: 1.1068e-04  
- accuracy: 1.0000 - val\_loss: 0.2136 - val\_accuracy: 0.9657  
Epoch 32/50  
103/103 [=====] - 6s 55ms/step - loss: 7.4879e-05  
- accuracy: 1.0000 - val\_loss: 0.2176 - val\_accuracy: 0.9669  
Epoch 33/50  
103/103 [=====] - 6s 59ms/step - loss: 7.5745e-05  
- accuracy: 1.0000 - val\_loss: 0.2240 - val\_accuracy: 0.9681  
Epoch 34/50  
103/103 [=====] - 6s 59ms/step - loss: 5.7430e-05  
- accuracy: 1.0000 - val\_loss: 0.2229 - val\_accuracy: 0.9645  
Epoch 35/50  
103/103 [=====] - 6s 55ms/step - loss: 6.9955e-05  
- accuracy: 1.0000 - val\_loss: 0.2303 - val\_accuracy: 0.9681  
Epoch 36/50  
103/103 [=====] - 6s 56ms/step - loss: 4.0486e-05  
- accuracy: 1.0000 - val\_loss: 0.2340 - val\_accuracy: 0.9669  
Epoch 37/50  
103/103 [=====] - 6s 57ms/step - loss: 5.2150e-05  
- accuracy: 1.0000 - val\_loss: 0.2448 - val\_accuracy: 0.9669  
Epoch 38/50

```

103/103 [=====] - 6s 57ms/step - loss: 4.3975e-05
- accuracy: 1.0000 - val_loss: 0.2357 - val_accuracy: 0.9669
Epoch 39/50
103/103 [=====] - 6s 58ms/step - loss: 3.2173e-05
- accuracy: 1.0000 - val_loss: 0.2386 - val_accuracy: 0.9632
Epoch 40/50
103/103 [=====] - 6s 58ms/step - loss: 2.6443e-05
- accuracy: 1.0000 - val_loss: 0.2442 - val_accuracy: 0.9681
Epoch 41/50
103/103 [=====] - 6s 58ms/step - loss: 3.3128e-05
- accuracy: 1.0000 - val_loss: 0.2433 - val_accuracy: 0.9669
Epoch 42/50
103/103 [=====] - 6s 59ms/step - loss: 2.2470e-05
- accuracy: 1.0000 - val_loss: 0.2486 - val_accuracy: 0.9681
Epoch 43/50
103/103 [=====] - 6s 56ms/step - loss: 2.0235e-05
- accuracy: 1.0000 - val_loss: 0.2471 - val_accuracy: 0.9669
Epoch 44/50
103/103 [=====] - 6s 56ms/step - loss: 1.8584e-05
- accuracy: 1.0000 - val_loss: 0.2460 - val_accuracy: 0.9681
Epoch 45/50
103/103 [=====] - 6s 59ms/step - loss: 1.8807e-05
- accuracy: 1.0000 - val_loss: 0.2470 - val_accuracy: 0.9681
Epoch 46/50
103/103 [=====] - 6s 60ms/step - loss: 1.5126e-05
- accuracy: 1.0000 - val_loss: 0.2499 - val_accuracy: 0.9681
Epoch 47/50
103/103 [=====] - 6s 57ms/step - loss: 1.4443e-05
- accuracy: 1.0000 - val_loss: 0.2520 - val_accuracy: 0.9681
Epoch 48/50
103/103 [=====] - 6s 59ms/step - loss: 1.3469e-05
- accuracy: 1.0000 - val_loss: 0.2546 - val_accuracy: 0.9669
Epoch 49/50
103/103 [=====] - 6s 57ms/step - loss: 1.1244e-05
- accuracy: 1.0000 - val_loss: 0.2563 - val_accuracy: 0.9694
Epoch 50/50
103/103 [=====] - 6s 58ms/step - loss: 1.2934e-05
- accuracy: 1.0000 - val_loss: 0.2560 - val_accuracy: 0.9681

```

```
In [74]: results_train = model3.evaluate(train_images, train_y)
```

```

103/103 [=====] - 1s 9ms/step - loss: 6.4655e-06 -
accuracy: 1.0000

```

```
In [75]: results_test = model3.evaluate(test_images, test_y)
```

```

55/55 [=====] - 1s 9ms/step - loss: 0.3134 - accur
acy: 0.9526

```

```
In [76]: results_train
```

```
Out[76]: [6.465525530074956e-06, 1.0]
```

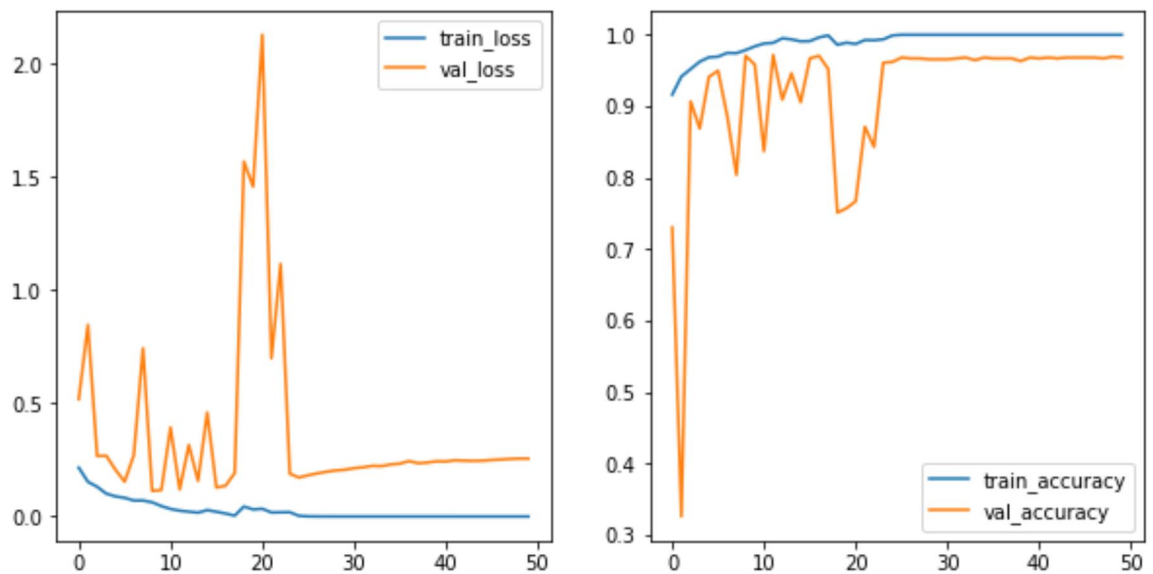
```
In [77]: results_test
```

```
Out[77]: [0.3133782744407654, 0.952625572681427]
```

```
In [78]: train_loss = history3.history['loss']
train_acc = history3.history['accuracy']
val_loss = history3.history['val_loss']
val_acc = history3.history['val_accuracy']

fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(10, 5))
sns.lineplot(x=history3.epoch, y=train_loss, ax=ax1, label='train_loss')
sns.lineplot(x=history3.epoch, y=train_acc, ax=ax2, label='train_accuracy')
sns.lineplot(x=history3.epoch, y=val_loss, ax=ax1, label='val_loss')
sns.lineplot(x=history3.epoch, y=val_acc, ax=ax2, label='val_accuracy')
```

```
Out[78]: <AxesSubplot: >
```



```
In [82]: #model 3. save('models/model_3.h5')
```



```
In [97]: cvs = cross_val_score(keras_model4, train_images , train_y, cv=5)
```

Epoch 1/50  
82/82 [=====] - 7s 81ms/step - loss: 0.2277 - accuracy: 0.9087 - val\_loss: 0.5137 - val\_accuracy: 0.7316  
Epoch 2/50  
82/82 [=====] - 6s 70ms/step - loss: 0.1536 - accuracy: 0.9404 - val\_loss: 0.5292 - val\_accuracy: 0.7304  
Epoch 3/50  
82/82 [=====] - 7s 84ms/step - loss: 0.1171 - accuracy: 0.9568 - val\_loss: 0.5714 - val\_accuracy: 0.7059  
Epoch 4/50  
82/82 [=====] - 5s 64ms/step - loss: 0.1003 - accuracy: 0.9664 - val\_loss: 0.4985 - val\_accuracy: 0.7316  
Epoch 5/50  
82/82 [=====] - 6s 70ms/step - loss: 0.1044 - accuracy: 0.9618 - val\_loss: 0.6640 - val\_accuracy: 0.7475  
Epoch 6/50  
82/82 [=====] - 6s 74ms/step - loss: 0.0984 - accuracy: 0.9656 - val\_loss: 0.4017 - val\_accuracy: 0.8174  
Epoch 7/50  
82/82 [=====] - 6s 71ms/step - loss: 0.0753 - accuracy: 0.9721 - val\_loss: 0.2998 - val\_accuracy: 0.8309  
Epoch 8/50  
82/82 [=====] - 6s 73ms/step - loss: 0.0602 - accuracy: 0.9778 - val\_loss: 0.2131 - val\_accuracy: 0.9240  
Epoch 9/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0545 - accuracy: 0.9782 - val\_loss: 0.1218 - val\_accuracy: 0.9596  
Epoch 10/50  
82/82 [=====] - 5s 67ms/step - loss: 0.0559 - accuracy: 0.9790 - val\_loss: 0.2651 - val\_accuracy: 0.9191  
Epoch 11/50  
82/82 [=====] - 6s 68ms/step - loss: 0.0368 - accuracy: 0.9878 - val\_loss: 0.1477 - val\_accuracy: 0.9473  
Epoch 12/50  
82/82 [=====] - 6s 69ms/step - loss: 0.0250 - accuracy: 0.9912 - val\_loss: 0.1515 - val\_accuracy: 0.9534  
Epoch 13/50  
82/82 [=====] - 6s 78ms/step - loss: 0.0138 - accuracy: 0.9969 - val\_loss: 0.2336 - val\_accuracy: 0.9338  
Epoch 14/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0278 - accuracy: 0.9874 - val\_loss: 0.2066 - val\_accuracy: 0.9265  
Epoch 15/50  
82/82 [=====] - 6s 68ms/step - loss: 0.0130 - accuracy: 0.9966 - val\_loss: 0.3387 - val\_accuracy: 0.9142  
Epoch 16/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0052 - accuracy: 0.9989 - val\_loss: 0.4362 - val\_accuracy: 0.8493  
Epoch 17/50  
82/82 [=====] - 6s 72ms/step - loss: 0.0053 - accuracy: 0.9985 - val\_loss: 0.8622 - val\_accuracy: 0.8652  
Epoch 18/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0079 - accuracy: 0.9985 - val\_loss: 0.4315 - val\_accuracy: 0.9301  
Epoch 19/50  
82/82 [=====] - 6s 74ms/step - loss: 0.0249 - accuracy: 0.9985 - val\_loss: 0.4315 - val\_accuracy: 0.9301



racy: 0.9924 - val\_loss: 0.3942 - val\_accuracy: 0.8444  
Epoch 20/50  
82/82 [=====] - 6s 79ms/step - loss: 0.0468 - accuracy: 0.9820 - val\_loss: 0.2590 - val\_accuracy: 0.9277  
Epoch 21/50  
82/82 [=====] - 6s 73ms/step - loss: 0.0504 - accuracy: 0.9805 - val\_loss: 0.3439 - val\_accuracy: 0.8995  
Epoch 22/50  
82/82 [=====] - 6s 75ms/step - loss: 0.0230 - accuracy: 0.9916 - val\_loss: 0.2215 - val\_accuracy: 0.9461  
Epoch 23/50  
82/82 [=====] - 7s 85ms/step - loss: 0.0112 - accuracy: 0.9962 - val\_loss: 0.1514 - val\_accuracy: 0.9522  
Epoch 24/50  
82/82 [=====] - 6s 71ms/step - loss: 0.0137 - accuracy: 0.9943 - val\_loss: 1.1596 - val\_accuracy: 0.8370  
Epoch 25/50  
82/82 [=====] - 6s 74ms/step - loss: 0.0035 - accuracy: 1.0000 - val\_loss: 0.2072 - val\_accuracy: 0.9632  
Epoch 26/50  
82/82 [=====] - 6s 69ms/step - loss: 0.0011 - accuracy: 1.0000 - val\_loss: 0.1951 - val\_accuracy: 0.9583  
Epoch 27/50  
82/82 [=====] - 6s 67ms/step - loss: 6.9371e-04 - accuracy: 1.0000 - val\_loss: 0.1987 - val\_accuracy: 0.9559  
Epoch 28/50  
82/82 [=====] - 5s 66ms/step - loss: 3.0251e-04 - accuracy: 1.0000 - val\_loss: 0.2048 - val\_accuracy: 0.9632  
Epoch 29/50  
82/82 [=====] - 6s 69ms/step - loss: 2.4045e-04 - accuracy: 1.0000 - val\_loss: 0.2107 - val\_accuracy: 0.9571  
Epoch 30/50  
82/82 [=====] - 6s 68ms/step - loss: 1.7660e-04 - accuracy: 1.0000 - val\_loss: 0.2132 - val\_accuracy: 0.9620  
Epoch 31/50  
82/82 [=====] - 5s 61ms/step - loss: 1.4280e-04 - accuracy: 1.0000 - val\_loss: 0.2168 - val\_accuracy: 0.9620  
Epoch 32/50  
82/82 [=====] - 5s 57ms/step - loss: 1.6315e-04 - accuracy: 1.0000 - val\_loss: 0.2250 - val\_accuracy: 0.9645  
Epoch 33/50  
82/82 [=====] - 5s 62ms/step - loss: 2.0327e-04 - accuracy: 1.0000 - val\_loss: 0.2205 - val\_accuracy: 0.9608  
Epoch 34/50  
82/82 [=====] - 5s 60ms/step - loss: 9.5926e-05 - accuracy: 1.0000 - val\_loss: 0.2369 - val\_accuracy: 0.9645  
Epoch 35/50  
82/82 [=====] - 5s 65ms/step - loss: 7.7675e-05 - accuracy: 1.0000 - val\_loss: 0.2347 - val\_accuracy: 0.9620  
Epoch 36/50  
82/82 [=====] - 6s 68ms/step - loss: 6.7177e-05 - accuracy: 1.0000 - val\_loss: 0.2386 - val\_accuracy: 0.9596  
Epoch 37/50  
82/82 [=====] - 5s 64ms/step - loss: 6.6259e-05 - accuracy: 1.0000 - val\_loss: 0.2374 - val\_accuracy: 0.9645  
Epoch 38/50

82/82 [=====] - 5s 64ms/step - loss: 5.7573e-05 - accuracy: 1.0000 - val\_loss: 0.2446 - val\_accuracy: 0.9669  
Epoch 39/50  
82/82 [=====] - 5s 67ms/step - loss: 3.8276e-05 - accuracy: 1.0000 - val\_loss: 0.2443 - val\_accuracy: 0.9608  
Epoch 40/50  
82/82 [=====] - 5s 64ms/step - loss: 8.5836e-05 - accuracy: 1.0000 - val\_loss: 0.2461 - val\_accuracy: 0.9669  
Epoch 41/50  
82/82 [=====] - 6s 69ms/step - loss: 4.0442e-05 - accuracy: 1.0000 - val\_loss: 0.2445 - val\_accuracy: 0.9608  
Epoch 42/50  
82/82 [=====] - 6s 68ms/step - loss: 5.1565e-05 - accuracy: 1.0000 - val\_loss: 0.2444 - val\_accuracy: 0.9608  
Epoch 43/50  
82/82 [=====] - 5s 63ms/step - loss: 3.9087e-05 - accuracy: 1.0000 - val\_loss: 0.2524 - val\_accuracy: 0.9571  
Epoch 44/50  
82/82 [=====] - 6s 67ms/step - loss: 2.5848e-05 - accuracy: 1.0000 - val\_loss: 0.2511 - val\_accuracy: 0.9632  
Epoch 45/50  
82/82 [=====] - 5s 64ms/step - loss: 4.4233e-05 - accuracy: 1.0000 - val\_loss: 0.2541 - val\_accuracy: 0.9657  
Epoch 46/50  
82/82 [=====] - 5s 61ms/step - loss: 2.2830e-05 - accuracy: 1.0000 - val\_loss: 0.2525 - val\_accuracy: 0.9632  
Epoch 47/50  
82/82 [=====] - 5s 67ms/step - loss: 2.7573e-05 - accuracy: 1.0000 - val\_loss: 0.2546 - val\_accuracy: 0.9632  
Epoch 48/50  
82/82 [=====] - 5s 67ms/step - loss: 2.0709e-05 - accuracy: 1.0000 - val\_loss: 0.2561 - val\_accuracy: 0.9632  
Epoch 49/50  
82/82 [=====] - 6s 69ms/step - loss: 1.9993e-05 - accuracy: 1.0000 - val\_loss: 0.2601 - val\_accuracy: 0.9645  
Epoch 50/50  
82/82 [=====] - 5s 63ms/step - loss: 2.7641e-05 - accuracy: 1.0000 - val\_loss: 0.2743 - val\_accuracy: 0.9645  
21/21 [=====] - 0s 9ms/step - loss: 0.2778 - accuracy: 0.9649  
Epoch 1/50  
82/82 [=====] - 6s 68ms/step - loss: 0.2392 - accuracy: 0.9003 - val\_loss: 0.5722 - val\_accuracy: 0.7304  
Epoch 2/50  
82/82 [=====] - 5s 64ms/step - loss: 0.1672 - accuracy: 0.9404 - val\_loss: 0.4963 - val\_accuracy: 0.7304  
Epoch 3/50  
82/82 [=====] - 5s 64ms/step - loss: 0.1145 - accuracy: 0.9606 - val\_loss: 0.3695 - val\_accuracy: 0.7439  
Epoch 4/50  
82/82 [=====] - 5s 64ms/step - loss: 0.1069 - accuracy: 0.9641 - val\_loss: 0.3954 - val\_accuracy: 0.7475  
Epoch 5/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0931 - accuracy: 0.9656 - val\_loss: 0.6029 - val\_accuracy: 0.7414  
Epoch 6/50

82/82 [=====] - 6s 67ms/step - loss: 0.0867 - accuracy: 0.9694 - val\_loss: 0.1815 - val\_accuracy: 0.9596  
Epoch 7/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0762 - accuracy: 0.9713 - val\_loss: 0.2957 - val\_accuracy: 0.8615  
Epoch 8/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0666 - accuracy: 0.9752 - val\_loss: 1.8379 - val\_accuracy: 0.7341  
Epoch 9/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0548 - accuracy: 0.9797 - val\_loss: 0.2652 - val\_accuracy: 0.9167  
Epoch 10/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0435 - accuracy: 0.9832 - val\_loss: 0.6829 - val\_accuracy: 0.8297  
Epoch 11/50  
82/82 [=====] - 6s 74ms/step - loss: 0.0273 - accuracy: 0.9901 - val\_loss: 0.1755 - val\_accuracy: 0.9547  
Epoch 12/50  
82/82 [=====] - 6s 76ms/step - loss: 0.0297 - accuracy: 0.9908 - val\_loss: 0.1709 - val\_accuracy: 0.9449  
Epoch 13/50  
82/82 [=====] - 6s 76ms/step - loss: 0.0282 - accuracy: 0.9897 - val\_loss: 0.2043 - val\_accuracy: 0.9375  
Epoch 14/50  
82/82 [=====] - 6s 72ms/step - loss: 0.0154 - accuracy: 0.9954 - val\_loss: 0.1509 - val\_accuracy: 0.9498  
Epoch 15/50  
82/82 [=====] - 6s 73ms/step - loss: 0.0107 - accuracy: 0.9973 - val\_loss: 0.2095 - val\_accuracy: 0.9498  
Epoch 16/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0499 - accuracy: 0.9836 - val\_loss: 0.1356 - val\_accuracy: 0.9608  
Epoch 17/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0123 - accuracy: 0.9973 - val\_loss: 0.1438 - val\_accuracy: 0.9571  
Epoch 18/50  
82/82 [=====] - 6s 70ms/step - loss: 0.0072 - accuracy: 0.9981 - val\_loss: 0.1660 - val\_accuracy: 0.9522  
Epoch 19/50  
82/82 [=====] - 5s 67ms/step - loss: 0.0094 - accuracy: 0.9962 - val\_loss: 0.2735 - val\_accuracy: 0.9338  
Epoch 20/50  
82/82 [=====] - 6s 68ms/step - loss: 0.0263 - accuracy: 0.9893 - val\_loss: 0.1597 - val\_accuracy: 0.9412  
Epoch 21/50  
82/82 [=====] - 6s 71ms/step - loss: 0.0287 - accuracy: 0.9885 - val\_loss: 0.0859 - val\_accuracy: 0.9669  
Epoch 22/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0335 - accuracy: 0.9874 - val\_loss: 0.1707 - val\_accuracy: 0.9424  
Epoch 23/50  
82/82 [=====] - 6s 67ms/step - loss: 0.0092 - accuracy: 0.9966 - val\_loss: 1.5230 - val\_accuracy: 0.7892  
Epoch 24/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0039 - accuracy: 0.9996 - val\_loss: 0.2081 - val\_accuracy: 0.9400

Epoch 25/50  
82/82 [=====] - 5s 65ms/step - loss: 5.3602e-04 - accuracy: 1.0000 - val\_loss: 0.1382 - val\_accuracy: 0.9694  
Epoch 26/50  
82/82 [=====] - 5s 62ms/step - loss: 3.1167e-04 - accuracy: 1.0000 - val\_loss: 0.1492 - val\_accuracy: 0.9669  
Epoch 27/50  
82/82 [=====] - 5s 65ms/step - loss: 2.9614e-04 - accuracy: 1.0000 - val\_loss: 0.2447 - val\_accuracy: 0.9534  
Epoch 28/50  
82/82 [=====] - 6s 70ms/step - loss: 1.4109e-04 - accuracy: 1.0000 - val\_loss: 0.1597 - val\_accuracy: 0.9730  
Epoch 29/50  
82/82 [=====] - 6s 69ms/step - loss: 1.4976e-04 - accuracy: 1.0000 - val\_loss: 0.1560 - val\_accuracy: 0.9718  
Epoch 30/50  
82/82 [=====] - 6s 67ms/step - loss: 9.7841e-05 - accuracy: 1.0000 - val\_loss: 0.1692 - val\_accuracy: 0.9681  
Epoch 31/50  
82/82 [=====] - 5s 64ms/step - loss: 6.4433e-05 - accuracy: 1.0000 - val\_loss: 0.1664 - val\_accuracy: 0.9681  
Epoch 32/50  
82/82 [=====] - 6s 73ms/step - loss: 9.0140e-05 - accuracy: 1.0000 - val\_loss: 0.1771 - val\_accuracy: 0.9681  
Epoch 33/50  
82/82 [=====] - 5s 64ms/step - loss: 1.0902e-04 - accuracy: 1.0000 - val\_loss: 0.1724 - val\_accuracy: 0.9706  
Epoch 34/50  
82/82 [=====] - 5s 67ms/step - loss: 5.2775e-05 - accuracy: 1.0000 - val\_loss: 0.1728 - val\_accuracy: 0.9694  
Epoch 35/50  
82/82 [=====] - 6s 69ms/step - loss: 4.0730e-05 - accuracy: 1.0000 - val\_loss: 0.1716 - val\_accuracy: 0.9718  
Epoch 36/50  
82/82 [=====] - 5s 62ms/step - loss: 6.0735e-05 - accuracy: 1.0000 - val\_loss: 0.1718 - val\_accuracy: 0.9706  
Epoch 37/50  
82/82 [=====] - 5s 63ms/step - loss: 4.0896e-05 - accuracy: 1.0000 - val\_loss: 0.1763 - val\_accuracy: 0.9681  
Epoch 38/50  
82/82 [=====] - 5s 65ms/step - loss: 5.3409e-05 - accuracy: 1.0000 - val\_loss: 0.1783 - val\_accuracy: 0.9718  
Epoch 39/50  
82/82 [=====] - 5s 63ms/step - loss: 3.2927e-05 - accuracy: 1.0000 - val\_loss: 0.1776 - val\_accuracy: 0.9718  
Epoch 40/50  
82/82 [=====] - 5s 63ms/step - loss: 3.1675e-05 - accuracy: 1.0000 - val\_loss: 0.1809 - val\_accuracy: 0.9706  
Epoch 41/50  
82/82 [=====] - 5s 64ms/step - loss: 2.7639e-05 - accuracy: 1.0000 - val\_loss: 0.1801 - val\_accuracy: 0.9743  
Epoch 42/50  
82/82 [=====] - 5s 65ms/step - loss: 2.9676e-05 - accuracy: 1.0000 - val\_loss: 0.1812 - val\_accuracy: 0.9718  
Epoch 43/50  
82/82 [=====] - 6s 71ms/step - loss: 2.5115e-05 -

accuracy: 1.0000 - val\_loss: 0.1894 - val\_accuracy: 0.9694  
Epoch 44/50  
82/82 [=====] - 6s 75ms/step - loss: 2.1877e-05 -  
accuracy: 1.0000 - val\_loss: 0.1857 - val\_accuracy: 0.9718  
Epoch 45/50  
82/82 [=====] - 5s 67ms/step - loss: 2.1298e-05 -  
accuracy: 1.0000 - val\_loss: 0.1883 - val\_accuracy: 0.9718  
Epoch 46/50  
82/82 [=====] - 6s 69ms/step - loss: 1.5240e-05 -  
accuracy: 1.0000 - val\_loss: 0.1852 - val\_accuracy: 0.9743  
Epoch 47/50  
82/82 [=====] - 6s 72ms/step - loss: 2.5858e-05 -  
accuracy: 1.0000 - val\_loss: 0.1874 - val\_accuracy: 0.9730  
Epoch 48/50  
82/82 [=====] - 5s 65ms/step - loss: 1.6451e-05 -  
accuracy: 1.0000 - val\_loss: 0.1874 - val\_accuracy: 0.9730  
Epoch 49/50  
82/82 [=====] - 6s 71ms/step - loss: 1.3430e-05 -  
accuracy: 1.0000 - val\_loss: 0.1877 - val\_accuracy: 0.9743  
Epoch 50/50  
82/82 [=====] - 5s 60ms/step - loss: 1.3661e-05 -  
accuracy: 1.0000 - val\_loss: 0.1905 - val\_accuracy: 0.9718  
21/21 [=====] - 0s 9ms/step - loss: 0.2492 - accu  
acy: 0.9527  
Epoch 1/50  
82/82 [=====] - 6s 62ms/step - loss: 0.2238 - accu  
racy: 0.9118 - val\_loss: 0.5636 - val\_accuracy: 0.7304  
Epoch 2/50  
82/82 [=====] - 5s 58ms/step - loss: 0.1523 - accu  
racy: 0.9473 - val\_loss: 0.7009 - val\_accuracy: 0.7304  
Epoch 3/50  
82/82 [=====] - 5s 66ms/step - loss: 0.1334 - accu  
racy: 0.9515 - val\_loss: 1.1556 - val\_accuracy: 0.7304  
Epoch 4/50  
82/82 [=====] - 6s 67ms/step - loss: 0.1129 - accu  
racy: 0.9591 - val\_loss: 0.3877 - val\_accuracy: 0.7831  
Epoch 5/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0953 - accu  
racy: 0.9672 - val\_loss: 0.4448 - val\_accuracy: 0.7757  
Epoch 6/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0849 - accu  
racy: 0.9702 - val\_loss: 0.1791 - val\_accuracy: 0.9228  
Epoch 7/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0734 - accu  
racy: 0.9752 - val\_loss: 0.2271 - val\_accuracy: 0.9032  
Epoch 8/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0584 - accu  
racy: 0.9771 - val\_loss: 0.1524 - val\_accuracy: 0.9498  
Epoch 9/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0475 - accu  
racy: 0.9832 - val\_loss: 0.1246 - val\_accuracy: 0.9522  
Epoch 10/50  
82/82 [=====] - 6s 74ms/step - loss: 0.0479 - accu  
racy: 0.9817 - val\_loss: 0.2427 - val\_accuracy: 0.9179  
Epoch 11/50  
82/82 [=====] - 6s 74ms/step - loss: 0.0354 - accu

racy: 0.9885 - val\_loss: 0.9171 - val\_accuracy: 0.8100  
Epoch 12/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0269 - accuracy: 0.9920 - val\_loss: 0.1320 - val\_accuracy: 0.9547  
Epoch 13/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0109 - accuracy: 0.9973 - val\_loss: 0.1391 - val\_accuracy: 0.9620  
Epoch 14/50  
82/82 [=====] - 6s 72ms/step - loss: 0.0067 - accuracy: 0.9985 - val\_loss: 0.1771 - val\_accuracy: 0.9596  
Epoch 15/50  
82/82 [=====] - 6s 72ms/step - loss: 0.0020 - accuracy: 1.0000 - val\_loss: 0.1828 - val\_accuracy: 0.9571  
Epoch 16/50  
82/82 [=====] - 6s 72ms/step - loss: 0.0019 - accuracy: 1.0000 - val\_loss: 0.1641 - val\_accuracy: 0.9608  
Epoch 17/50  
82/82 [=====] - 6s 68ms/step - loss: 6.2327e-04 - accuracy: 1.0000 - val\_loss: 0.1481 - val\_accuracy: 0.9645  
Epoch 18/50  
82/82 [=====] - 7s 82ms/step - loss: 2.3633e-04 - accuracy: 1.0000 - val\_loss: 0.1543 - val\_accuracy: 0.9657  
Epoch 19/50  
82/82 [=====] - 6s 74ms/step - loss: 1.6181e-04 - accuracy: 1.0000 - val\_loss: 0.1610 - val\_accuracy: 0.9620  
Epoch 20/50  
82/82 [=====] - 7s 82ms/step - loss: 1.1242e-04 - accuracy: 1.0000 - val\_loss: 0.1642 - val\_accuracy: 0.9620  
Epoch 21/50  
82/82 [=====] - 7s 80ms/step - loss: 9.6737e-05 - accuracy: 1.0000 - val\_loss: 0.1754 - val\_accuracy: 0.9608  
Epoch 22/50  
82/82 [=====] - 6s 68ms/step - loss: 6.8796e-05 - accuracy: 1.0000 - val\_loss: 0.1729 - val\_accuracy: 0.9620  
Epoch 23/50  
82/82 [=====] - 5s 59ms/step - loss: 1.1425e-04 - accuracy: 1.0000 - val\_loss: 0.1710 - val\_accuracy: 0.9608  
Epoch 24/50  
82/82 [=====] - 5s 63ms/step - loss: 1.6994e-04 - accuracy: 1.0000 - val\_loss: 0.2162 - val\_accuracy: 0.9559  
Epoch 25/50  
82/82 [=====] - 5s 61ms/step - loss: 5.4547e-05 - accuracy: 1.0000 - val\_loss: 0.1915 - val\_accuracy: 0.9620  
Epoch 26/50  
82/82 [=====] - 6s 69ms/step - loss: 6.6611e-05 - accuracy: 1.0000 - val\_loss: 0.1988 - val\_accuracy: 0.9596  
Epoch 27/50  
82/82 [=====] - 6s 69ms/step - loss: 7.2967e-05 - accuracy: 1.0000 - val\_loss: 0.1991 - val\_accuracy: 0.9669  
Epoch 28/50  
82/82 [=====] - 6s 69ms/step - loss: 6.4344e-05 - accuracy: 1.0000 - val\_loss: 0.1981 - val\_accuracy: 0.9608  
Epoch 29/50  
82/82 [=====] - 6s 69ms/step - loss: 4.2025e-05 - accuracy: 1.0000 - val\_loss: 0.1973 - val\_accuracy: 0.9620  
Epoch 30/50

82/82 [=====] - 5s 63ms/step - loss: 3.1290e-05 - accuracy: 1.0000 - val\_loss: 0.1969 - val\_accuracy: 0.9608  
Epoch 31/50  
82/82 [=====] - 5s 63ms/step - loss: 4.7865e-05 - accuracy: 1.0000 - val\_loss: 0.1926 - val\_accuracy: 0.9608  
Epoch 32/50  
82/82 [=====] - 6s 70ms/step - loss: 2.3864e-05 - accuracy: 1.0000 - val\_loss: 0.1925 - val\_accuracy: 0.9608  
Epoch 33/50  
82/82 [=====] - 5s 63ms/step - loss: 2.8706e-05 - accuracy: 1.0000 - val\_loss: 0.1932 - val\_accuracy: 0.9620  
Epoch 34/50  
82/82 [=====] - 6s 69ms/step - loss: 1.9819e-05 - accuracy: 1.0000 - val\_loss: 0.1918 - val\_accuracy: 0.9620  
Epoch 35/50  
82/82 [=====] - 5s 62ms/step - loss: 1.9315e-05 - accuracy: 1.0000 - val\_loss: 0.1943 - val\_accuracy: 0.9632  
Epoch 36/50  
82/82 [=====] - 5s 62ms/step - loss: 1.8358e-05 - accuracy: 1.0000 - val\_loss: 0.1948 - val\_accuracy: 0.9620  
Epoch 37/50  
82/82 [=====] - 5s 67ms/step - loss: 1.7828e-05 - accuracy: 1.0000 - val\_loss: 0.1964 - val\_accuracy: 0.9645  
Epoch 38/50  
82/82 [=====] - 5s 63ms/step - loss: 1.6603e-05 - accuracy: 1.0000 - val\_loss: 0.1981 - val\_accuracy: 0.9632  
Epoch 39/50  
82/82 [=====] - 6s 68ms/step - loss: 1.2929e-05 - accuracy: 1.0000 - val\_loss: 0.1988 - val\_accuracy: 0.9632  
Epoch 40/50  
82/82 [=====] - 7s 82ms/step - loss: 1.4310e-05 - accuracy: 1.0000 - val\_loss: 0.2000 - val\_accuracy: 0.9620  
Epoch 41/50  
82/82 [=====] - 6s 74ms/step - loss: 1.5799e-05 - accuracy: 1.0000 - val\_loss: 0.2014 - val\_accuracy: 0.9620  
Epoch 42/50  
82/82 [=====] - 5s 67ms/step - loss: 1.6028e-05 - accuracy: 1.0000 - val\_loss: 0.2059 - val\_accuracy: 0.9620  
Epoch 43/50  
82/82 [=====] - 5s 65ms/step - loss: 1.7045e-05 - accuracy: 1.0000 - val\_loss: 0.2057 - val\_accuracy: 0.9620  
Epoch 44/50  
82/82 [=====] - 5s 64ms/step - loss: 1.1950e-05 - accuracy: 1.0000 - val\_loss: 0.2013 - val\_accuracy: 0.9620  
Epoch 45/50  
82/82 [=====] - 6s 68ms/step - loss: 6.5425e-06 - accuracy: 1.0000 - val\_loss: 0.2044 - val\_accuracy: 0.9620  
Epoch 46/50  
82/82 [=====] - 6s 71ms/step - loss: 9.0946e-06 - accuracy: 1.0000 - val\_loss: 0.2067 - val\_accuracy: 0.9620  
Epoch 47/50  
82/82 [=====] - 6s 71ms/step - loss: 6.6559e-06 - accuracy: 1.0000 - val\_loss: 0.2061 - val\_accuracy: 0.9620  
Epoch 48/50  
82/82 [=====] - 5s 57ms/step - loss: 1.6558e-05 - accuracy: 1.0000 - val\_loss: 0.2083 - val\_accuracy: 0.9620

Epoch 49/50  
82/82 [=====] - 5s 59ms/step - loss: 7.8325e-06 - accuracy: 1.0000 - val\_loss: 0.2067 - val\_accuracy: 0.9645  
Epoch 50/50  
82/82 [=====] - 5s 62ms/step - loss: 1.1237e-05 - accuracy: 1.0000 - val\_loss: 0.2051 - val\_accuracy: 0.9608  
21/21 [=====] - 0s 10ms/step - loss: 0.2421 - accuracy: 0.9602  
Epoch 1/50  
82/82 [=====] - 6s 64ms/step - loss: 0.2477 - accuracy: 0.9060 - val\_loss: 0.5335 - val\_accuracy: 0.7304  
Epoch 2/50  
82/82 [=====] - 5s 61ms/step - loss: 0.1408 - accuracy: 0.9511 - val\_loss: 0.4274 - val\_accuracy: 0.8358  
Epoch 3/50  
82/82 [=====] - 5s 64ms/step - loss: 0.1206 - accuracy: 0.9526 - val\_loss: 0.7186 - val\_accuracy: 0.7304  
Epoch 4/50  
82/82 [=====] - 5s 64ms/step - loss: 0.1200 - accuracy: 0.9538 - val\_loss: 1.0190 - val\_accuracy: 0.7304  
Epoch 5/50  
82/82 [=====] - 5s 61ms/step - loss: 0.1057 - accuracy: 0.9603 - val\_loss: 0.5399 - val\_accuracy: 0.7659  
Epoch 6/50  
82/82 [=====] - 6s 68ms/step - loss: 0.0885 - accuracy: 0.9675 - val\_loss: 0.4043 - val\_accuracy: 0.7831  
Epoch 7/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0816 - accuracy: 0.9733 - val\_loss: 1.1222 - val\_accuracy: 0.7328  
Epoch 8/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0710 - accuracy: 0.9733 - val\_loss: 0.1393 - val\_accuracy: 0.9498  
Epoch 9/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0567 - accuracy: 0.9790 - val\_loss: 0.5270 - val\_accuracy: 0.7917  
Epoch 10/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0368 - accuracy: 0.9870 - val\_loss: 0.1037 - val\_accuracy: 0.9620  
Epoch 11/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0400 - accuracy: 0.9847 - val\_loss: 0.5438 - val\_accuracy: 0.7794  
Epoch 12/50  
82/82 [=====] - 6s 70ms/step - loss: 0.0452 - accuracy: 0.9847 - val\_loss: 4.3321 - val\_accuracy: 0.7304  
Epoch 13/50  
82/82 [=====] - 6s 68ms/step - loss: 0.0263 - accuracy: 0.9905 - val\_loss: 0.2179 - val\_accuracy: 0.9167  
Epoch 14/50  
82/82 [=====] - 6s 71ms/step - loss: 0.0262 - accuracy: 0.9905 - val\_loss: 0.1474 - val\_accuracy: 0.9534  
Epoch 15/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0164 - accuracy: 0.9943 - val\_loss: 0.3185 - val\_accuracy: 0.9252  
Epoch 16/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0241 - accuracy: 0.9920 - val\_loss: 0.8064 - val\_accuracy: 0.7990



Epoch 17/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0532 - accuracy: 0.9809 - val\_loss: 0.2698 - val\_accuracy: 0.9350  
Epoch 18/50  
82/82 [=====] - 6s 68ms/step - loss: 0.0322 - accuracy: 0.9885 - val\_loss: 0.1551 - val\_accuracy: 0.9596  
Epoch 19/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0146 - accuracy: 0.9958 - val\_loss: 0.2015 - val\_accuracy: 0.9375  
Epoch 20/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0054 - accuracy: 0.9996 - val\_loss: 0.1305 - val\_accuracy: 0.9681  
Epoch 21/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0032 - accuracy: 0.9992 - val\_loss: 0.1463 - val\_accuracy: 0.9608  
Epoch 22/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0102 - accuracy: 0.9950 - val\_loss: 0.1534 - val\_accuracy: 0.9645  
Epoch 23/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0079 - accuracy: 0.9977 - val\_loss: 0.2178 - val\_accuracy: 0.9559  
Epoch 24/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0078 - accuracy: 0.9977 - val\_loss: 0.1897 - val\_accuracy: 0.9363  
Epoch 25/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0110 - accuracy: 0.9969 - val\_loss: 0.2097 - val\_accuracy: 0.9424  
Epoch 26/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0013 - accuracy: 1.0000 - val\_loss: 0.1517 - val\_accuracy: 0.9620  
Epoch 27/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0219 - accuracy: 0.9916 - val\_loss: 0.1627 - val\_accuracy: 0.9681  
Epoch 28/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0573 - accuracy: 0.9790 - val\_loss: 2.4793 - val\_accuracy: 0.7316  
Epoch 29/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0468 - accuracy: 0.9847 - val\_loss: 0.3337 - val\_accuracy: 0.8627  
Epoch 30/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0199 - accuracy: 0.9947 - val\_loss: 0.1614 - val\_accuracy: 0.9522  
Epoch 31/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0141 - accuracy: 0.9954 - val\_loss: 0.3563 - val\_accuracy: 0.8775  
Epoch 32/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0237 - accuracy: 0.9908 - val\_loss: 1.8672 - val\_accuracy: 0.7978  
Epoch 33/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0139 - accuracy: 0.9947 - val\_loss: 0.1656 - val\_accuracy: 0.9547  
Epoch 34/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0053 - accuracy: 0.9977 - val\_loss: 0.2561 - val\_accuracy: 0.9522  
Epoch 35/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0012 - accuracy:

racy: 1.0000 - val\_loss: 0.1805 - val\_accuracy: 0.9694  
Epoch 36/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0012 - accuracy: 0.9996 - val\_loss: 0.1763 - val\_accuracy: 0.9694  
Epoch 37/50  
82/82 [=====] - 5s 61ms/step - loss: 4.8838e-04 - accuracy: 1.0000 - val\_loss: 0.1818 - val\_accuracy: 0.9608  
Epoch 38/50  
82/82 [=====] - 5s 60ms/step - loss: 2.0127e-04 - accuracy: 1.0000 - val\_loss: 0.1877 - val\_accuracy: 0.9694  
Epoch 39/50  
82/82 [=====] - 5s 64ms/step - loss: 1.6572e-04 - accuracy: 1.0000 - val\_loss: 0.1977 - val\_accuracy: 0.9620  
Epoch 40/50  
82/82 [=====] - 5s 60ms/step - loss: 6.1126e-04 - accuracy: 0.9996 - val\_loss: 0.2133 - val\_accuracy: 0.9645  
Epoch 41/50  
82/82 [=====] - 5s 60ms/step - loss: 1.1896e-04 - accuracy: 1.0000 - val\_loss: 0.2103 - val\_accuracy: 0.9657  
Epoch 42/50  
82/82 [=====] - 5s 64ms/step - loss: 9.7385e-05 - accuracy: 1.0000 - val\_loss: 0.2192 - val\_accuracy: 0.9645  
Epoch 43/50  
82/82 [=====] - 5s 60ms/step - loss: 7.0467e-05 - accuracy: 1.0000 - val\_loss: 0.2162 - val\_accuracy: 0.9669  
Epoch 44/50  
82/82 [=====] - 5s 62ms/step - loss: 5.8482e-05 - accuracy: 1.0000 - val\_loss: 0.2193 - val\_accuracy: 0.9669  
Epoch 45/50  
82/82 [=====] - 5s 55ms/step - loss: 8.5156e-05 - accuracy: 1.0000 - val\_loss: 0.2277 - val\_accuracy: 0.9620  
Epoch 46/50  
82/82 [=====] - 5s 58ms/step - loss: 5.4812e-05 - accuracy: 1.0000 - val\_loss: 0.2183 - val\_accuracy: 0.9669  
Epoch 47/50  
82/82 [=====] - 5s 64ms/step - loss: 7.2374e-05 - accuracy: 1.0000 - val\_loss: 0.2218 - val\_accuracy: 0.9669  
Epoch 48/50  
82/82 [=====] - 5s 58ms/step - loss: 4.1416e-05 - accuracy: 1.0000 - val\_loss: 0.2228 - val\_accuracy: 0.9669  
Epoch 49/50  
82/82 [=====] - 5s 61ms/step - loss: 3.0380e-05 - accuracy: 1.0000 - val\_loss: 0.2240 - val\_accuracy: 0.9681  
Epoch 50/50  
82/82 [=====] - 5s 62ms/step - loss: 3.7407e-05 - accuracy: 1.0000 - val\_loss: 0.2254 - val\_accuracy: 0.9681  
21/21 [=====] - 0s 9ms/step - loss: 0.3435 - accuracy: 0.9526  
Epoch 1/50  
82/82 [=====] - 5s 60ms/step - loss: 0.2334 - accuracy: 0.9099 - val\_loss: 0.5902 - val\_accuracy: 0.7304  
Epoch 2/50  
82/82 [=====] - 5s 62ms/step - loss: 0.1613 - accuracy: 0.9446 - val\_loss: 0.6035 - val\_accuracy: 0.7304  
Epoch 3/50  
82/82 [=====] - 5s 66ms/step - loss: 0.1405 - accuracy:

racy: 0.9507 - val\_loss: 0.5110 - val\_accuracy: 0.7304  
Epoch 4/50  
82/82 [=====] - 5s 60ms/step - loss: 0.1158 - accu  
racy: 0.9549 - val\_loss: 0.3123 - val\_accuracy: 0.8297  
Epoch 5/50  
82/82 [=====] - 5s 56ms/step - loss: 0.1009 - accu  
racy: 0.9652 - val\_loss: 0.2138 - val\_accuracy: 0.9277  
Epoch 6/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0962 - accu  
racy: 0.9660 - val\_loss: 1.4611 - val\_accuracy: 0.7304  
Epoch 7/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0754 - accu  
racy: 0.9733 - val\_loss: 0.1525 - val\_accuracy: 0.9449  
Epoch 8/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0554 - accu  
racy: 0.9813 - val\_loss: 0.1860 - val\_accuracy: 0.9240  
Epoch 9/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0464 - accu  
racy: 0.9820 - val\_loss: 0.3328 - val\_accuracy: 0.8517  
Epoch 10/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0490 - accu  
racy: 0.9847 - val\_loss: 0.1340 - val\_accuracy: 0.9645  
Epoch 11/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0482 - accu  
racy: 0.9820 - val\_loss: 0.2574 - val\_accuracy: 0.8958  
Epoch 12/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0654 - accu  
racy: 0.9763 - val\_loss: 0.2122 - val\_accuracy: 0.9350  
Epoch 13/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0545 - accu  
racy: 0.9801 - val\_loss: 1.0369 - val\_accuracy: 0.7929  
Epoch 14/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0382 - accu  
racy: 0.9851 - val\_loss: 0.3779 - val\_accuracy: 0.8909  
Epoch 15/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0237 - accu  
racy: 0.9924 - val\_loss: 1.1113 - val\_accuracy: 0.7855  
Epoch 16/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0239 - accu  
racy: 0.9912 - val\_loss: 0.1612 - val\_accuracy: 0.9510  
Epoch 17/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0269 - accu  
racy: 0.9885 - val\_loss: 0.1811 - val\_accuracy: 0.9412  
Epoch 18/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0136 - accu  
racy: 0.9950 - val\_loss: 2.1452 - val\_accuracy: 0.7414  
Epoch 19/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0408 - accu  
racy: 0.9882 - val\_loss: 0.1517 - val\_accuracy: 0.9547  
Epoch 20/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0238 - accu  
racy: 0.9916 - val\_loss: 0.1311 - val\_accuracy: 0.9620  
Epoch 21/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0418 - accu  
racy: 0.9847 - val\_loss: 0.2128 - val\_accuracy: 0.9485  
Epoch 22/50

82/82 [=====] - 5s 61ms/step - loss: 0.0201 - accuracy: 0.9916 - val\_loss: 0.1077 - val\_accuracy: 0.9681  
Epoch 23/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0068 - accuracy: 0.9981 - val\_loss: 0.2279 - val\_accuracy: 0.9265  
Epoch 24/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0023 - accuracy: 0.9996 - val\_loss: 0.1483 - val\_accuracy: 0.9645  
Epoch 25/50  
82/82 [=====] - 5s 63ms/step - loss: 9.0321e-04 - accuracy: 1.0000 - val\_loss: 0.1732 - val\_accuracy: 0.9571  
Epoch 26/50  
82/82 [=====] - 5s 63ms/step - loss: 4.5408e-04 - accuracy: 1.0000 - val\_loss: 0.1775 - val\_accuracy: 0.9669  
Epoch 27/50  
82/82 [=====] - 5s 62ms/step - loss: 5.3771e-04 - accuracy: 1.0000 - val\_loss: 0.1919 - val\_accuracy: 0.9681  
Epoch 28/50  
82/82 [=====] - 5s 58ms/step - loss: 4.0428e-04 - accuracy: 1.0000 - val\_loss: 0.1992 - val\_accuracy: 0.9571  
Epoch 29/50  
82/82 [=====] - 5s 64ms/step - loss: 1.9703e-04 - accuracy: 1.0000 - val\_loss: 0.1944 - val\_accuracy: 0.9632  
Epoch 30/50  
82/82 [=====] - 5s 60ms/step - loss: 1.5567e-04 - accuracy: 1.0000 - val\_loss: 0.1971 - val\_accuracy: 0.9608  
Epoch 31/50  
82/82 [=====] - 5s 64ms/step - loss: 1.3007e-04 - accuracy: 1.0000 - val\_loss: 0.2011 - val\_accuracy: 0.9596  
Epoch 32/50  
82/82 [=====] - 5s 58ms/step - loss: 9.7244e-05 - accuracy: 1.0000 - val\_loss: 0.2061 - val\_accuracy: 0.9645  
Epoch 33/50  
82/82 [=====] - 5s 58ms/step - loss: 8.3482e-05 - accuracy: 1.0000 - val\_loss: 0.2056 - val\_accuracy: 0.9632  
Epoch 34/50  
82/82 [=====] - 5s 61ms/step - loss: 1.5111e-04 - accuracy: 1.0000 - val\_loss: 0.2066 - val\_accuracy: 0.9632  
Epoch 35/50  
82/82 [=====] - 5s 65ms/step - loss: 9.7120e-05 - accuracy: 1.0000 - val\_loss: 0.2093 - val\_accuracy: 0.9632  
Epoch 36/50  
82/82 [=====] - 5s 62ms/step - loss: 5.2134e-05 - accuracy: 1.0000 - val\_loss: 0.2087 - val\_accuracy: 0.9608  
Epoch 37/50  
82/82 [=====] - 5s 60ms/step - loss: 7.3435e-05 - accuracy: 1.0000 - val\_loss: 0.2117 - val\_accuracy: 0.9632  
Epoch 38/50  
82/82 [=====] - 5s 62ms/step - loss: 5.1992e-05 - accuracy: 1.0000 - val\_loss: 0.2107 - val\_accuracy: 0.9620  
Epoch 39/50  
82/82 [=====] - 5s 64ms/step - loss: 4.1237e-05 - accuracy: 1.0000 - val\_loss: 0.2103 - val\_accuracy: 0.9608  
Epoch 40/50  
82/82 [=====] - 5s 59ms/step - loss: 4.9968e-05 - accuracy: 1.0000 - val\_loss: 0.2129 - val\_accuracy: 0.9620

```

Epoch 41/50
82/82 [=====] - 5s 61ms/step - loss: 3.4273e-05 -
accuracy: 1.0000 - val_loss: 0.2115 - val_accuracy: 0.9620
Epoch 42/50
82/82 [=====] - 5s 62ms/step - loss: 4.6664e-05 -
accuracy: 1.0000 - val_loss: 0.2122 - val_accuracy: 0.9632
Epoch 43/50
82/82 [=====] - 5s 59ms/step - loss: 3.8065e-05 -
accuracy: 1.0000 - val_loss: 0.2149 - val_accuracy: 0.9620
Epoch 44/50
82/82 [=====] - 5s 58ms/step - loss: 3.1537e-05 -
accuracy: 1.0000 - val_loss: 0.2167 - val_accuracy: 0.9632
Epoch 45/50
82/82 [=====] - 5s 63ms/step - loss: 2.8284e-05 -
accuracy: 1.0000 - val_loss: 0.2147 - val_accuracy: 0.9620
Epoch 46/50
82/82 [=====] - 5s 59ms/step - loss: 3.5614e-05 -
accuracy: 1.0000 - val_loss: 0.2154 - val_accuracy: 0.9608
Epoch 47/50
82/82 [=====] - 5s 60ms/step - loss: 2.9138e-05 -
accuracy: 1.0000 - val_loss: 0.2172 - val_accuracy: 0.9657
Epoch 48/50
82/82 [=====] - 5s 58ms/step - loss: 4.9049e-05 -
accuracy: 1.0000 - val_loss: 0.2235 - val_accuracy: 0.9620
Epoch 49/50
82/82 [=====] - 5s 57ms/step - loss: 2.8523e-05 -
accuracy: 1.0000 - val_loss: 0.2201 - val_accuracy: 0.9608

```

```
In [98]: save_result('CNN #3', results_train[1], results_test[1], cvs[0], cvs[1], cvs[2], cvs[3], cvs[4])
```

Out[98]:

	model_name	Train Accuracy	Test Accuracy	CV1	CV2	CV3	CV4	CV5	CV_Std	CV_avg
0	CNN #3	1.000	0.953	0.965	0.953	0.960	0.953	0.966	0.007	0.959
0	CNN #2	1.000	0.947	0.953	0.956	0.960	0.953	0.963	0.005	0.957
0	CNN #1	0.953	0.933	0.921	0.940	0.931	0.916	0.945	0.012	0.931
0	Initial Model	0.730	0.730	0.925	0.740	0.728	0.709	0.743	0.088	0.769

## Prediction for Confusion Matrix

```
In [99]: predictions = model3.predict(x = test_images, steps = 10, verbose=0)
```

```
In [100]: pred_check = np.round(predictions)
```

```
In [101]: pred_check = pred_check[:]
pred_check = pred_check.flatten()
pred_check
```

Out[101]: array([1., 1., 1., ..., 0., 0., 0.], dtype=float32)

```
In [102]: test_check = test_labels[:,0]
test_check
```

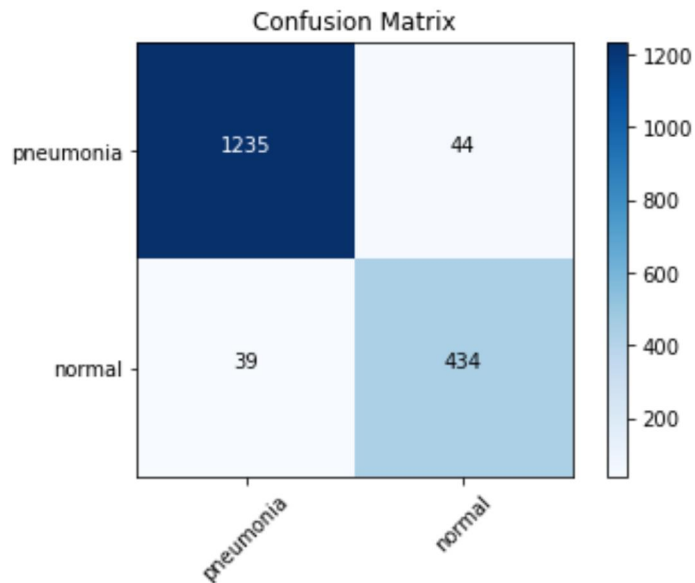
```
Out[102]: array([1., 1., 1., ..., 0., 0., 0.], dtype=float32)
```

```
In [103]: cm = confusion_matrix(y_true=test_check, y_pred=pred_check)
```

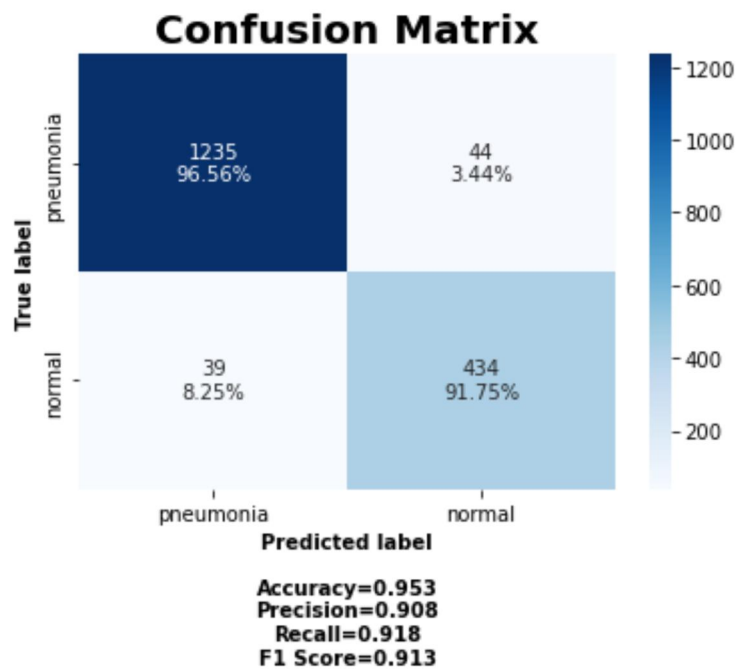
```
In [104]: cm_plot_labels = ['pneumonia', 'normal']
plot_confusion_matrix(cm=cm, classes=cm_plot_labels, title='Confusion Matrix')
```

Confusion matrix, without normalization

```
[[1235  44]
 [ 39 434]]
```



```
In [105]: cm_plot_labels = ['pneumonia', 'normal']
make_confusion_matrix(cm, categories = cm_plot_labels, title='Confusion Matrix')
```



## CNN Model 4

For this model, I will add weights

```
In [106]: norm_tot = len(os.listdir('re-split_data/train/normal'))
pneu_tot = len(os.listdir('re-split_data/train/pneumonia'))
norm_weight = norm_tot / (norm_tot + pneu_tot)
pneu_weight = pneu_tot / (norm_tot + pneu_tot)

print(f' normal weight is {round(norm_weight,2)}, pneumonia weight is {round(pneu_weight,2)}')
```

normal weight is 0.27, pneumonia weight is 0.73

```
In [107]: classWeight = {0 : norm_weight, 1 : pneu_weight}
```

```
In [108]: model 4 = models.Sequential()

model 4.add(layers.Conv2D(32, (3, 3), activation='relu', input_shape=(64, 64, 3)))
model 4.add(layers.MaxPooling2D((2, 2)))

model 4.add(layers.Conv2D(32, (4, 4), activation='relu'))
model 4.add(BatchNormalization())
model 4.add(layers.MaxPooling2D((2, 2)))

model 4.add(layers.Conv2D(64, (3, 3), activation='relu'))
model 4.add(layers.MaxPooling2D((2, 2)))

model 4.add(layers.Conv2D(128, (3, 3), activation='relu'))
model 4.add(BatchNormalization())
model 4.add(layers.MaxPooling2D((2, 2)))

model 4.add(layers.Flatten())
model 4.add(layers.Dense(64, activation='relu'))
model 4.add(Dropout(0.1))
model 4.add(layers.Dense(1, activation='sigmoid'))

model 4.compile(loss='binary_crossentropy',
                optimizer="adam",
                metrics=['accuracy'])
```





Epoch 1/50  
103/103 [=====] - 7s 60ms/step - loss: 0.0985 - accuracy: 0.9086 - val\_loss: 0.5111 - val\_accuracy: 0.7304

Epoch 2/50  
103/103 [=====] - 6s 60ms/step - loss: 0.0603 - accuracy: 0.9386 - val\_loss: 0.4544 - val\_accuracy: 0.7304

Epoch 3/50  
103/103 [=====] - 6s 63ms/step - loss: 0.0595 - accuracy: 0.9468 - val\_loss: 0.2467 - val\_accuracy: 0.9105

Epoch 4/50  
103/103 [=====] - 6s 58ms/step - loss: 0.0509 - accuracy: 0.9505 - val\_loss: 0.1766 - val\_accuracy: 0.9375

Epoch 5/50  
103/103 [=====] - 6s 59ms/step - loss: 0.0411 - accuracy: 0.9609 - val\_loss: 0.3124 - val\_accuracy: 0.8689

Epoch 6/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0374 - accuracy: 0.9667 - val\_loss: 0.2796 - val\_accuracy: 0.8824

Epoch 7/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0354 - accuracy: 0.9667 - val\_loss: 0.1355 - val\_accuracy: 0.9473

Epoch 8/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0276 - accuracy: 0.9725 - val\_loss: 2.7341 - val\_accuracy: 0.7304

Epoch 9/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0366 - accuracy: 0.9642 - val\_loss: 1.2525 - val\_accuracy: 0.7868

Epoch 10/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0312 - accuracy: 0.9697 - val\_loss: 0.1484 - val\_accuracy: 0.9473

Epoch 11/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0199 - accuracy: 0.9838 - val\_loss: 0.3073 - val\_accuracy: 0.8958

Epoch 12/50  
103/103 [=====] - 6s 58ms/step - loss: 0.0171 - accuracy: 0.9838 - val\_loss: 1.1553 - val\_accuracy: 0.7819

Epoch 13/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0086 - accuracy: 0.9914 - val\_loss: 0.1167 - val\_accuracy: 0.9718

Epoch 14/50  
103/103 [=====] - 6s 59ms/step - loss: 0.0068 - accuracy: 0.9951 - val\_loss: 0.2757 - val\_accuracy: 0.9350

Epoch 15/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0042 - accuracy: 0.9954 - val\_loss: 0.4061 - val\_accuracy: 0.9130

Epoch 16/50  
103/103 [=====] - 6s 63ms/step - loss: 0.0099 - accuracy: 0.9927 - val\_loss: 0.1597 - val\_accuracy: 0.9534

Epoch 17/50  
103/103 [=====] - 7s 66ms/step - loss: 0.0203 - accuracy: 0.9835 - val\_loss: 0.1438 - val\_accuracy: 0.9547

Epoch 18/50  
103/103 [=====] - 6s 62ms/step - loss: 0.0147 - accuracy: 0.9862 - val\_loss: 0.1446 - val\_accuracy: 0.9620

Epoch 19/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0107 - accuracy: 0.9862 - val\_loss: 0.1446 - val\_accuracy: 0.9620

curacy: 0.9899 - val\_loss: 0.2958 - val\_accuracy: 0.9400  
Epoch 20/50  
103/103 [=====] - 6s 59ms/step - loss: 0.0061 - accuracy: 0.9939 - val\_loss: 0.1254 - val\_accuracy: 0.9657  
Epoch 21/50  
103/103 [=====] - 6s 59ms/step - loss: 0.0016 - accuracy: 0.9988 - val\_loss: 0.1400 - val\_accuracy: 0.9669  
Epoch 22/50  
103/103 [=====] - 6s 61ms/step - loss: 0.0035 - accuracy: 0.9976 - val\_loss: 0.4672 - val\_accuracy: 0.8505  
Epoch 23/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0102 - accuracy: 0.9905 - val\_loss: 0.3888 - val\_accuracy: 0.9203  
Epoch 24/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0396 - accuracy: 0.9642 - val\_loss: 0.2049 - val\_accuracy: 0.9350  
Epoch 25/50  
103/103 [=====] - 6s 58ms/step - loss: 0.0164 - accuracy: 0.9847 - val\_loss: 0.1528 - val\_accuracy: 0.9412  
Epoch 26/50  
103/103 [=====] - 6s 62ms/step - loss: 0.0069 - accuracy: 0.9945 - val\_loss: 0.1325 - val\_accuracy: 0.9632  
Epoch 27/50  
103/103 [=====] - 6s 55ms/step - loss: 0.0085 - accuracy: 0.9927 - val\_loss: 0.1691 - val\_accuracy: 0.9547  
Epoch 28/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0181 - accuracy: 0.9829 - val\_loss: 0.1800 - val\_accuracy: 0.9473  
Epoch 29/50  
103/103 [=====] - 6s 59ms/step - loss: 0.0067 - accuracy: 0.9939 - val\_loss: 0.1171 - val\_accuracy: 0.9620  
Epoch 30/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0044 - accuracy: 0.9945 - val\_loss: 0.3937 - val\_accuracy: 0.9338  
Epoch 31/50  
103/103 [=====] - 6s 58ms/step - loss: 0.0016 - accuracy: 0.9991 - val\_loss: 0.1685 - val\_accuracy: 0.9657  
Epoch 32/50  
103/103 [=====] - 6s 58ms/step - loss: 6.0384e-04 - accuracy: 0.9997 - val\_loss: 0.1814 - val\_accuracy: 0.9645  
Epoch 33/50  
103/103 [=====] - 6s 56ms/step - loss: 2.1244e-04 - accuracy: 1.0000 - val\_loss: 0.2047 - val\_accuracy: 0.9645  
Epoch 34/50  
103/103 [=====] - 6s 58ms/step - loss: 1.1674e-04 - accuracy: 1.0000 - val\_loss: 0.1993 - val\_accuracy: 0.9669  
Epoch 35/50  
103/103 [=====] - 6s 56ms/step - loss: 1.0401e-04 - accuracy: 1.0000 - val\_loss: 0.2048 - val\_accuracy: 0.9657  
Epoch 36/50  
103/103 [=====] - 6s 54ms/step - loss: 6.3537e-05 - accuracy: 1.0000 - val\_loss: 0.2007 - val\_accuracy: 0.9669  
Epoch 37/50  
103/103 [=====] - 6s 56ms/step - loss: 5.1347e-05 - accuracy: 1.0000 - val\_loss: 0.2036 - val\_accuracy: 0.9669  
Epoch 38/50

```

103/103 [=====] - 6s 55ms/step - loss: 4.5278e-05
- accuracy: 1.0000 - val_loss: 0.2095 - val_accuracy: 0.9669
Epoch 39/50
103/103 [=====] - 6s 55ms/step - loss: 5.5721e-05
- accuracy: 1.0000 - val_loss: 0.2096 - val_accuracy: 0.9669
Epoch 40/50
103/103 [=====] - 6s 58ms/step - loss: 3.5168e-05
- accuracy: 1.0000 - val_loss: 0.2117 - val_accuracy: 0.9681
Epoch 41/50
103/103 [=====] - 6s 55ms/step - loss: 4.1366e-05
- accuracy: 1.0000 - val_loss: 0.2238 - val_accuracy: 0.9645
Epoch 42/50
103/103 [=====] - 6s 57ms/step - loss: 2.0795e-05
- accuracy: 1.0000 - val_loss: 0.2224 - val_accuracy: 0.9645
Epoch 43/50
103/103 [=====] - 6s 58ms/step - loss: 2.0114e-05
- accuracy: 1.0000 - val_loss: 0.2180 - val_accuracy: 0.9669
Epoch 44/50
103/103 [=====] - 7s 68ms/step - loss: 2.2694e-05
- accuracy: 1.0000 - val_loss: 0.2193 - val_accuracy: 0.9669
Epoch 45/50
103/103 [=====] - 7s 66ms/step - loss: 1.6644e-05
- accuracy: 1.0000 - val_loss: 0.2250 - val_accuracy: 0.9657
Epoch 46/50
103/103 [=====] - 6s 61ms/step - loss: 1.6001e-05
- accuracy: 1.0000 - val_loss: 0.2216 - val_accuracy: 0.9669
Epoch 47/50
103/103 [=====] - 6s 61ms/step - loss: 1.5532e-05
- accuracy: 1.0000 - val_loss: 0.2234 - val_accuracy: 0.9669
Epoch 48/50
103/103 [=====] - 7s 63ms/step - loss: 1.2906e-05
- accuracy: 1.0000 - val_loss: 0.2279 - val_accuracy: 0.9669
Epoch 49/50
103/103 [=====] - 7s 64ms/step - loss: 1.9652e-05
- accuracy: 1.0000 - val_loss: 0.2379 - val_accuracy: 0.9620
Epoch 50/50
103/103 [=====] - 6s 63ms/step - loss: 6.3627e-05
- accuracy: 1.0000 - val_loss: 0.2361 - val_accuracy: 0.9657

```

```
In [110]: results_train = model4.evaluate(train_images, train_y)
```

```

103/103 [=====] - 1s 11ms/step - loss: 1.6202e-05
- accuracy: 1.0000

```

```
In [111]: results_test = model4.evaluate(test_images, test_y)
```

```

55/55 [=====] - 1s 11ms/step - loss: 0.3341 - accuracy: 0.9503

```

```
In [112]: results_train
```

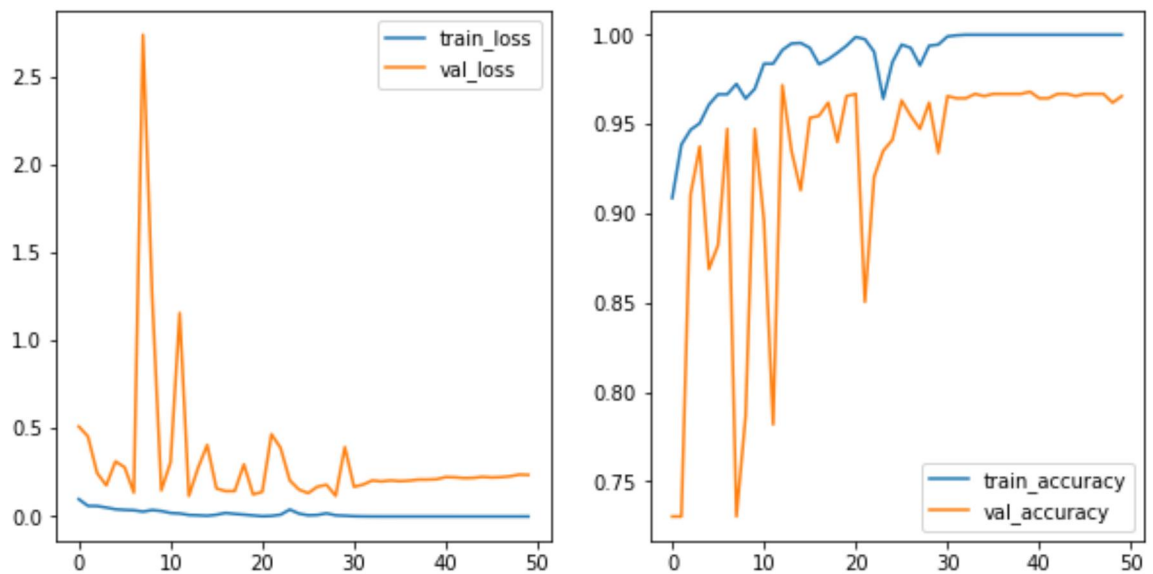
```
Out[112]: [1.620161856408231e-05, 1.0]
```

```
In [113]: results_test
```

```
Out[113]: [0.3341217339038849, 0.9503424763679504]
```

```
In [114]: train_loss = history4.history['loss']  
train_acc = history4.history['accuracy']  
val_loss = history4.history['val_loss']  
val_acc = history4.history['val_accuracy']  
  
fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(10, 5))  
sns.lineplot(x=history4.epoch, y=train_loss, ax=ax1, label='train_loss')  
sns.lineplot(x=history4.epoch, y=train_acc, ax=ax2, label='train_accuracy')  
sns.lineplot(x=history4.epoch, y=val_loss, ax=ax1, label='val_loss')  
sns.lineplot(x=history4.epoch, y=val_acc, ax=ax2, label='val_accuracy')
```

```
Out[114]: <AxesSubplot: >
```



```
In [115]: def build_cnn5():
    model = models.Sequential()

    model.add(layers.Conv2D(32, (3, 3), activation='relu', input_shape=(64, 64, 3)))
    model.add(layers.MaxPooling2D((2, 2)))

    model.add(layers.Conv2D(32, (4, 4), activation='relu'))
    model.add(layers.BatchNormalization())
    model.add(layers.MaxPooling2D((2, 2)))

    model.add(layers.Conv2D(64, (3, 3), activation='relu'))
    model.add(layers.MaxPooling2D((2, 2)))

    model.add(layers.Conv2D(128, (3, 3), activation='relu'))
    model.add(layers.BatchNormalization())
    model.add(layers.MaxPooling2D((2, 2)))

    model.add(layers.Flatten())
    model.add(layers.Dense(64, activation='relu'))
    model.add(layers.Dropout(0.1))
    model.add(layers.Dense(1, activation='sigmoid'))

    model.compile(loss='binary_crossentropy',
                  optimizer='adam',
                  metrics=['accuracy'])

    return model
```

[illegible]

```
In [117]: cvs = cross_val_score(keras_model5, train_images , train_y, cv=5)
```

Epoch 1/50  
82/82 [=====] - 7s 74ms/step - loss: 0.2419 - accuracy: 0.9060 - val\_loss: 0.5333 - val\_accuracy: 0.7304  
Epoch 2/50  
82/82 [=====] - 6s 71ms/step - loss: 0.1680 - accuracy: 0.9324 - val\_loss: 0.7791 - val\_accuracy: 0.7304  
Epoch 3/50  
82/82 [=====] - 5s 67ms/step - loss: 0.1362 - accuracy: 0.9488 - val\_loss: 0.8507 - val\_accuracy: 0.3664  
Epoch 4/50  
82/82 [=====] - 5s 66ms/step - loss: 0.1017 - accuracy: 0.9660 - val\_loss: 0.4821 - val\_accuracy: 0.7439  
Epoch 5/50  
82/82 [=====] - 5s 65ms/step - loss: 0.1016 - accuracy: 0.9637 - val\_loss: 0.2166 - val\_accuracy: 0.9387  
Epoch 6/50  
82/82 [=====] - 6s 68ms/step - loss: 0.0925 - accuracy: 0.9637 - val\_loss: 0.2601 - val\_accuracy: 0.9093  
Epoch 7/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0835 - accuracy: 0.9729 - val\_loss: 0.1851 - val\_accuracy: 0.9252  
Epoch 8/50  
82/82 [=====] - 6s 70ms/step - loss: 0.0816 - accuracy: 0.9687 - val\_loss: 1.3362 - val\_accuracy: 0.7463  
Epoch 9/50  
82/82 [=====] - 6s 68ms/step - loss: 0.0574 - accuracy: 0.9797 - val\_loss: 0.6003 - val\_accuracy: 0.8480  
Epoch 10/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0378 - accuracy: 0.9897 - val\_loss: 1.5775 - val\_accuracy: 0.4963  
Epoch 11/50  
82/82 [=====] - 6s 69ms/step - loss: 0.0392 - accuracy: 0.9855 - val\_loss: 0.7014 - val\_accuracy: 0.7574  
Epoch 12/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0378 - accuracy: 0.9843 - val\_loss: 0.2357 - val\_accuracy: 0.9081  
Epoch 13/50  
82/82 [=====] - 6s 68ms/step - loss: 0.0475 - accuracy: 0.9813 - val\_loss: 0.4334 - val\_accuracy: 0.8346  
Epoch 14/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0327 - accuracy: 0.9904 - val\_loss: 7.3044 - val\_accuracy: 0.7304  
Epoch 15/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0262 - accuracy: 0.9912 - val\_loss: 0.0886 - val\_accuracy: 0.9730  
Epoch 16/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0211 - accuracy: 0.9939 - val\_loss: 0.1911 - val\_accuracy: 0.9436  
Epoch 17/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0111 - accuracy: 0.9966 - val\_loss: 0.2021 - val\_accuracy: 0.9412  
Epoch 18/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0095 - accuracy: 0.9962 - val\_loss: 0.1375 - val\_accuracy: 0.9522  
Epoch 19/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0034 - accuracy:



racy: 0.9989 - val\_loss: 0.1254 - val\_accuracy: 0.9681  
Epoch 20/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0011 - accuracy: 1.0000 - val\_loss: 0.1645 - val\_accuracy: 0.9596  
Epoch 21/50  
82/82 [=====] - 5s 66ms/step - loss: 4.9814e-04 - accuracy: 1.0000 - val\_loss: 0.1504 - val\_accuracy: 0.9669  
Epoch 22/50  
82/82 [=====] - 5s 63ms/step - loss: 3.0463e-04 - accuracy: 1.0000 - val\_loss: 0.1569 - val\_accuracy: 0.9669  
Epoch 23/50  
82/82 [=====] - 5s 66ms/step - loss: 2.3298e-04 - accuracy: 1.0000 - val\_loss: 0.1613 - val\_accuracy: 0.9718  
Epoch 24/50  
82/82 [=====] - 5s 63ms/step - loss: 1.3342e-04 - accuracy: 1.0000 - val\_loss: 0.1681 - val\_accuracy: 0.9669  
Epoch 25/50  
82/82 [=====] - 5s 63ms/step - loss: 1.0772e-04 - accuracy: 1.0000 - val\_loss: 0.1769 - val\_accuracy: 0.9657  
Epoch 26/50  
82/82 [=====] - 5s 57ms/step - loss: 1.2890e-04 - accuracy: 1.0000 - val\_loss: 0.1739 - val\_accuracy: 0.9694  
Epoch 27/50  
82/82 [=====] - 5s 59ms/step - loss: 9.5907e-05 - accuracy: 1.0000 - val\_loss: 0.1788 - val\_accuracy: 0.9706  
Epoch 28/50  
82/82 [=====] - 5s 55ms/step - loss: 9.0908e-05 - accuracy: 1.0000 - val\_loss: 0.1879 - val\_accuracy: 0.9657  
Epoch 29/50  
82/82 [=====] - 5s 58ms/step - loss: 1.2072e-04 - accuracy: 1.0000 - val\_loss: 0.1870 - val\_accuracy: 0.9657  
Epoch 30/50  
82/82 [=====] - 5s 59ms/step - loss: 5.0235e-05 - accuracy: 1.0000 - val\_loss: 0.1888 - val\_accuracy: 0.9657  
Epoch 31/50  
82/82 [=====] - 5s 61ms/step - loss: 7.4644e-05 - accuracy: 1.0000 - val\_loss: 0.1899 - val\_accuracy: 0.9669  
Epoch 32/50  
82/82 [=====] - 5s 63ms/step - loss: 4.9187e-05 - accuracy: 1.0000 - val\_loss: 0.1887 - val\_accuracy: 0.9669  
Epoch 33/50  
82/82 [=====] - 5s 59ms/step - loss: 5.0966e-05 - accuracy: 1.0000 - val\_loss: 0.1889 - val\_accuracy: 0.9669  
Epoch 34/50  
82/82 [=====] - 5s 66ms/step - loss: 2.5849e-05 - accuracy: 1.0000 - val\_loss: 0.1899 - val\_accuracy: 0.9669  
Epoch 35/50  
82/82 [=====] - 5s 65ms/step - loss: 3.8649e-05 - accuracy: 1.0000 - val\_loss: 0.1917 - val\_accuracy: 0.9669  
Epoch 36/50  
82/82 [=====] - 6s 68ms/step - loss: 4.3497e-05 - accuracy: 1.0000 - val\_loss: 0.1997 - val\_accuracy: 0.9657  
Epoch 37/50  
82/82 [=====] - 5s 67ms/step - loss: 3.1587e-05 - accuracy: 1.0000 - val\_loss: 0.1961 - val\_accuracy: 0.9669  
Epoch 38/50

82/82 [=====] - 6s 70ms/step - loss: 3.4219e-05 - accuracy: 1.0000 - val\_loss: 0.1972 - val\_accuracy: 0.9669  
Epoch 39/50  
82/82 [=====] - 5s 66ms/step - loss: 2.5950e-05 - accuracy: 1.0000 - val\_loss: 0.1973 - val\_accuracy: 0.9669  
Epoch 40/50  
82/82 [=====] - 5s 63ms/step - loss: 3.3146e-05 - accuracy: 1.0000 - val\_loss: 0.2087 - val\_accuracy: 0.9657  
Epoch 41/50  
82/82 [=====] - 5s 65ms/step - loss: 3.3844e-05 - accuracy: 1.0000 - val\_loss: 0.2100 - val\_accuracy: 0.9632  
Epoch 42/50  
82/82 [=====] - 5s 66ms/step - loss: 3.9611e-05 - accuracy: 1.0000 - val\_loss: 0.1947 - val\_accuracy: 0.9730  
Epoch 43/50  
82/82 [=====] - 5s 66ms/step - loss: 2.4846e-05 - accuracy: 1.0000 - val\_loss: 0.2050 - val\_accuracy: 0.9657  
Epoch 44/50  
82/82 [=====] - 5s 61ms/step - loss: 1.9657e-05 - accuracy: 1.0000 - val\_loss: 0.2028 - val\_accuracy: 0.9694  
Epoch 45/50  
82/82 [=====] - 5s 62ms/step - loss: 1.4290e-04 - accuracy: 1.0000 - val\_loss: 0.2413 - val\_accuracy: 0.9632  
Epoch 46/50  
82/82 [=====] - 5s 58ms/step - loss: 1.4291e-04 - accuracy: 1.0000 - val\_loss: 0.3191 - val\_accuracy: 0.9449  
Epoch 47/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0816 - accuracy: 0.9713 - val\_loss: 27.7754 - val\_accuracy: 0.2696  
Epoch 48/50  
82/82 [=====] - 5s 64ms/step - loss: 0.1405 - accuracy: 0.9480 - val\_loss: 1.0568 - val\_accuracy: 0.7475  
Epoch 49/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0797 - accuracy: 0.9721 - val\_loss: 0.1057 - val\_accuracy: 0.9632  
Epoch 50/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0516 - accuracy: 0.9820 - val\_loss: 0.6634 - val\_accuracy: 0.7745  
21/21 [=====] - 0s 10ms/step - loss: 0.6511 - accuracy: 0.7756  
Epoch 1/50  
82/82 [=====] - 6s 64ms/step - loss: 0.2228 - accuracy: 0.9144 - val\_loss: 0.5072 - val\_accuracy: 0.7304  
Epoch 2/50  
82/82 [=====] - 5s 64ms/step - loss: 0.1504 - accuracy: 0.9454 - val\_loss: 0.4897 - val\_accuracy: 0.7304  
Epoch 3/50  
82/82 [=====] - 5s 65ms/step - loss: 0.1179 - accuracy: 0.9564 - val\_loss: 0.3180 - val\_accuracy: 0.9044  
Epoch 4/50  
82/82 [=====] - 5s 66ms/step - loss: 0.1088 - accuracy: 0.9595 - val\_loss: 0.3654 - val\_accuracy: 0.7843  
Epoch 5/50  
82/82 [=====] - 7s 83ms/step - loss: 0.0868 - accuracy: 0.9698 - val\_loss: 0.1246 - val\_accuracy: 0.9596  
Epoch 6/50

82/82 [=====] - 5s 63ms/step - loss: 0.0896 - accuracy: 0.9656 - val\_loss: 0.3338 - val\_accuracy: 0.8591  
Epoch 7/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0948 - accuracy: 0.9648 - val\_loss: 0.1307 - val\_accuracy: 0.9620  
Epoch 8/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0745 - accuracy: 0.9694 - val\_loss: 2.0028 - val\_accuracy: 0.3689  
Epoch 9/50  
82/82 [=====] - 5s 66ms/step - loss: 0.0578 - accuracy: 0.9782 - val\_loss: 0.4342 - val\_accuracy: 0.8640  
Epoch 10/50  
82/82 [=====] - 6s 70ms/step - loss: 0.0455 - accuracy: 0.9859 - val\_loss: 0.2455 - val\_accuracy: 0.9118  
Epoch 11/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0297 - accuracy: 0.9897 - val\_loss: 0.1664 - val\_accuracy: 0.9449  
Epoch 12/50  
82/82 [=====] - 6s 68ms/step - loss: 0.0187 - accuracy: 0.9920 - val\_loss: 0.1279 - val\_accuracy: 0.9596  
Epoch 13/50  
82/82 [=====] - 6s 68ms/step - loss: 0.0149 - accuracy: 0.9958 - val\_loss: 1.3242 - val\_accuracy: 0.7917  
Epoch 14/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0287 - accuracy: 0.9912 - val\_loss: 0.9598 - val\_accuracy: 0.8100  
Epoch 15/50  
82/82 [=====] - 5s 66ms/step - loss: 0.0389 - accuracy: 0.9851 - val\_loss: 0.2349 - val\_accuracy: 0.9375  
Epoch 16/50  
82/82 [=====] - 5s 66ms/step - loss: 0.0111 - accuracy: 0.9966 - val\_loss: 0.5756 - val\_accuracy: 0.8885  
Epoch 17/50  
82/82 [=====] - 5s 66ms/step - loss: 0.0101 - accuracy: 0.9966 - val\_loss: 0.1391 - val\_accuracy: 0.9559  
Epoch 18/50  
82/82 [=====] - 5s 66ms/step - loss: 0.0219 - accuracy: 0.9916 - val\_loss: 0.3648 - val\_accuracy: 0.8468  
Epoch 19/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0433 - accuracy: 0.9843 - val\_loss: 0.1766 - val\_accuracy: 0.9436  
Epoch 20/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0125 - accuracy: 0.9958 - val\_loss: 0.2109 - val\_accuracy: 0.9350  
Epoch 21/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0206 - accuracy: 0.9912 - val\_loss: 0.7062 - val\_accuracy: 0.7794  
Epoch 22/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0279 - accuracy: 0.9916 - val\_loss: 0.9829 - val\_accuracy: 0.8346  
Epoch 23/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0293 - accuracy: 0.9874 - val\_loss: 2.5762 - val\_accuracy: 0.7316  
Epoch 24/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0156 - accuracy: 0.9943 - val\_loss: 0.1281 - val\_accuracy: 0.9669

Epoch 25/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0130 - accuracy: 0.9966 - val\_loss: 0.8012 - val\_accuracy: 0.8860  
Epoch 26/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0079 - accuracy: 0.9977 - val\_loss: 0.1773 - val\_accuracy: 0.9620  
Epoch 27/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0068 - accuracy: 0.9985 - val\_loss: 0.4420 - val\_accuracy: 0.8909  
Epoch 28/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0035 - accuracy: 0.9989 - val\_loss: 0.5323 - val\_accuracy: 0.9277  
Epoch 29/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0028 - accuracy: 0.9992 - val\_loss: 0.1791 - val\_accuracy: 0.9583  
Epoch 30/50  
82/82 [=====] - 5s 66ms/step - loss: 5.1502e-04 - accuracy: 1.0000 - val\_loss: 0.1799 - val\_accuracy: 0.9632  
Epoch 31/50  
82/82 [=====] - 5s 63ms/step - loss: 2.4951e-04 - accuracy: 1.0000 - val\_loss: 0.1752 - val\_accuracy: 0.9657  
Epoch 32/50  
82/82 [=====] - 5s 65ms/step - loss: 1.9620e-04 - accuracy: 1.0000 - val\_loss: 0.1806 - val\_accuracy: 0.9645  
Epoch 33/50  
82/82 [=====] - 5s 64ms/step - loss: 1.6752e-04 - accuracy: 1.0000 - val\_loss: 0.2023 - val\_accuracy: 0.9718  
Epoch 34/50  
82/82 [=====] - 6s 68ms/step - loss: 1.1241e-04 - accuracy: 1.0000 - val\_loss: 0.2031 - val\_accuracy: 0.9718  
Epoch 35/50  
82/82 [=====] - 5s 63ms/step - loss: 1.0215e-04 - accuracy: 1.0000 - val\_loss: 0.1918 - val\_accuracy: 0.9718  
Epoch 36/50  
82/82 [=====] - 5s 65ms/step - loss: 1.1573e-04 - accuracy: 1.0000 - val\_loss: 0.1920 - val\_accuracy: 0.9694  
Epoch 37/50  
82/82 [=====] - 5s 64ms/step - loss: 8.0417e-05 - accuracy: 1.0000 - val\_loss: 0.1908 - val\_accuracy: 0.9718  
Epoch 38/50  
82/82 [=====] - 5s 65ms/step - loss: 6.4842e-05 - accuracy: 1.0000 - val\_loss: 0.1954 - val\_accuracy: 0.9718  
Epoch 39/50  
82/82 [=====] - 5s 61ms/step - loss: 4.3697e-05 - accuracy: 1.0000 - val\_loss: 0.2015 - val\_accuracy: 0.9730  
Epoch 40/50  
82/82 [=====] - 5s 67ms/step - loss: 6.3270e-05 - accuracy: 1.0000 - val\_loss: 0.2072 - val\_accuracy: 0.9718  
Epoch 41/50  
82/82 [=====] - 5s 66ms/step - loss: 3.9063e-05 - accuracy: 1.0000 - val\_loss: 0.2044 - val\_accuracy: 0.9730  
Epoch 42/50  
82/82 [=====] - 5s 63ms/step - loss: 3.4258e-05 - accuracy: 1.0000 - val\_loss: 0.2078 - val\_accuracy: 0.9718  
Epoch 43/50  
82/82 [=====] - 5s 65ms/step - loss: 3.5531e-05 -

accuracy: 1.0000 - val\_loss: 0.2046 - val\_accuracy: 0.9718  
Epoch 44/50  
82/82 [=====] - 5s 66ms/step - loss: 3.2917e-05 -  
accuracy: 1.0000 - val\_loss: 0.2088 - val\_accuracy: 0.9730  
Epoch 45/50  
82/82 [=====] - 5s 65ms/step - loss: 2.7988e-05 -  
accuracy: 1.0000 - val\_loss: 0.2088 - val\_accuracy: 0.9730  
Epoch 46/50  
82/82 [=====] - 5s 66ms/step - loss: 3.1945e-05 -  
accuracy: 1.0000 - val\_loss: 0.2077 - val\_accuracy: 0.9730  
Epoch 47/50  
82/82 [=====] - 5s 63ms/step - loss: 2.3949e-05 -  
accuracy: 1.0000 - val\_loss: 0.2077 - val\_accuracy: 0.9730  
Epoch 48/50  
82/82 [=====] - 5s 63ms/step - loss: 2.7657e-05 -  
accuracy: 1.0000 - val\_loss: 0.2082 - val\_accuracy: 0.9694  
Epoch 49/50  
82/82 [=====] - 5s 63ms/step - loss: 1.8438e-05 -  
accuracy: 1.0000 - val\_loss: 0.2089 - val\_accuracy: 0.9681  
Epoch 50/50  
82/82 [=====] - 5s 63ms/step - loss: 1.6466e-05 -  
accuracy: 1.0000 - val\_loss: 0.2126 - val\_accuracy: 0.9718  
21/21 [=====] - 0s 12ms/step - loss: 0.2391 - accu  
racy: 0.9634  
Epoch 1/50  
82/82 [=====] - 6s 63ms/step - loss: 0.2348 - accu  
racy: 0.9121 - val\_loss: 0.6684 - val\_accuracy: 0.6716  
Epoch 2/50  
82/82 [=====] - 5s 63ms/step - loss: 0.1431 - accu  
racy: 0.9477 - val\_loss: 0.9242 - val\_accuracy: 0.2708  
Epoch 3/50  
82/82 [=====] - 5s 64ms/step - loss: 0.1342 - accu  
racy: 0.9534 - val\_loss: 0.6715 - val\_accuracy: 0.5576  
Epoch 4/50  
82/82 [=====] - 5s 66ms/step - loss: 0.1015 - accu  
racy: 0.9660 - val\_loss: 0.4296 - val\_accuracy: 0.8652  
Epoch 5/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0902 - accu  
racy: 0.9668 - val\_loss: 0.3078 - val\_accuracy: 0.8762  
Epoch 6/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0809 - accu  
racy: 0.9694 - val\_loss: 0.3907 - val\_accuracy: 0.7868  
Epoch 7/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0973 - accu  
racy: 0.9622 - val\_loss: 0.3799 - val\_accuracy: 0.8321  
Epoch 8/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0572 - accu  
racy: 0.9801 - val\_loss: 0.1049 - val\_accuracy: 0.9669  
Epoch 9/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0505 - accu  
racy: 0.9836 - val\_loss: 0.1746 - val\_accuracy: 0.9375  
Epoch 10/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0467 - accu  
racy: 0.9855 - val\_loss: 0.2625 - val\_accuracy: 0.8909  
Epoch 11/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0597 - accu

racy: 0.9782 - val\_loss: 0.1838 - val\_accuracy: 0.9375  
Epoch 12/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0456 - accu  
racy: 0.9840 - val\_loss: 0.1265 - val\_accuracy: 0.9596  
Epoch 13/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0211 - accu  
racy: 0.9931 - val\_loss: 0.2293 - val\_accuracy: 0.9400  
Epoch 14/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0145 - accu  
racy: 0.9950 - val\_loss: 0.1411 - val\_accuracy: 0.9436  
Epoch 15/50  
82/82 [=====] - 6s 68ms/step - loss: 0.0149 - accu  
racy: 0.9962 - val\_loss: 0.7508 - val\_accuracy: 0.7868  
Epoch 16/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0194 - accu  
racy: 0.9931 - val\_loss: 0.8189 - val\_accuracy: 0.8554  
Epoch 17/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0337 - accu  
racy: 0.9866 - val\_loss: 0.2634 - val\_accuracy: 0.9252  
Epoch 18/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0219 - accu  
racy: 0.9927 - val\_loss: 0.8322 - val\_accuracy: 0.8370  
Epoch 19/50  
82/82 [=====] - 6s 69ms/step - loss: 0.0154 - accu  
racy: 0.9943 - val\_loss: 0.2009 - val\_accuracy: 0.9485  
Epoch 20/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0048 - accu  
racy: 0.9985 - val\_loss: 1.4418 - val\_accuracy: 0.8186  
Epoch 21/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0121 - accu  
racy: 0.9958 - val\_loss: 0.2103 - val\_accuracy: 0.9547  
Epoch 22/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0074 - accu  
racy: 0.9969 - val\_loss: 0.2052 - val\_accuracy: 0.9449  
Epoch 23/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0114 - accu  
racy: 0.9962 - val\_loss: 0.2814 - val\_accuracy: 0.9350  
Epoch 24/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0144 - accu  
racy: 0.9954 - val\_loss: 0.4744 - val\_accuracy: 0.8824  
Epoch 25/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0593 - accu  
racy: 0.9775 - val\_loss: 0.4866 - val\_accuracy: 0.8211  
Epoch 26/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0124 - accu  
racy: 0.9962 - val\_loss: 0.4099 - val\_accuracy: 0.8897  
Epoch 27/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0146 - accu  
racy: 0.9927 - val\_loss: 0.4827 - val\_accuracy: 0.8480  
Epoch 28/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0039 - accu  
racy: 0.9992 - val\_loss: 0.2132 - val\_accuracy: 0.9522  
Epoch 29/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0022 - accu  
racy: 1.0000 - val\_loss: 0.2160 - val\_accuracy: 0.9449  
Epoch 30/50

82/82 [=====] - 5s 64ms/step - loss: 0.0010 - accuracy: 1.0000 - val\_loss: 0.2616 - val\_accuracy: 0.9473  
Epoch 31/50  
82/82 [=====] - 5s 62ms/step - loss: 2.6070e-04 - accuracy: 1.0000 - val\_loss: 0.2482 - val\_accuracy: 0.9510  
Epoch 32/50  
82/82 [=====] - 5s 62ms/step - loss: 2.1124e-04 - accuracy: 1.0000 - val\_loss: 0.2440 - val\_accuracy: 0.9534  
Epoch 33/50  
82/82 [=====] - 5s 61ms/step - loss: 2.3257e-04 - accuracy: 1.0000 - val\_loss: 0.2572 - val\_accuracy: 0.9522  
Epoch 34/50  
82/82 [=====] - 5s 65ms/step - loss: 8.7290e-05 - accuracy: 1.0000 - val\_loss: 0.2632 - val\_accuracy: 0.9522  
Epoch 35/50  
82/82 [=====] - 5s 65ms/step - loss: 9.2328e-05 - accuracy: 1.0000 - val\_loss: 0.2555 - val\_accuracy: 0.9534  
Epoch 36/50  
82/82 [=====] - 5s 66ms/step - loss: 9.7552e-05 - accuracy: 1.0000 - val\_loss: 0.2831 - val\_accuracy: 0.9534  
Epoch 37/50  
82/82 [=====] - 5s 64ms/step - loss: 5.0879e-05 - accuracy: 1.0000 - val\_loss: 0.2628 - val\_accuracy: 0.9534  
Epoch 38/50  
82/82 [=====] - 5s 60ms/step - loss: 4.3504e-05 - accuracy: 1.0000 - val\_loss: 0.2587 - val\_accuracy: 0.9534  
Epoch 39/50  
82/82 [=====] - 5s 60ms/step - loss: 5.6257e-05 - accuracy: 1.0000 - val\_loss: 0.2621 - val\_accuracy: 0.9534  
Epoch 40/50  
82/82 [=====] - 5s 63ms/step - loss: 4.8368e-05 - accuracy: 1.0000 - val\_loss: 0.2624 - val\_accuracy: 0.9534  
Epoch 41/50  
82/82 [=====] - 5s 64ms/step - loss: 4.3446e-05 - accuracy: 1.0000 - val\_loss: 0.2670 - val\_accuracy: 0.9534  
Epoch 42/50  
82/82 [=====] - 5s 62ms/step - loss: 2.9523e-05 - accuracy: 1.0000 - val\_loss: 0.2704 - val\_accuracy: 0.9522  
Epoch 43/50  
82/82 [=====] - 5s 64ms/step - loss: 3.8959e-05 - accuracy: 1.0000 - val\_loss: 0.2715 - val\_accuracy: 0.9522  
Epoch 44/50  
82/82 [=====] - 5s 64ms/step - loss: 6.3338e-05 - accuracy: 1.0000 - val\_loss: 0.2900 - val\_accuracy: 0.9547  
Epoch 45/50  
82/82 [=====] - 5s 63ms/step - loss: 5.0668e-05 - accuracy: 1.0000 - val\_loss: 0.2820 - val\_accuracy: 0.9534  
Epoch 46/50  
82/82 [=====] - 5s 65ms/step - loss: 2.4690e-05 - accuracy: 1.0000 - val\_loss: 0.2799 - val\_accuracy: 0.9534  
Epoch 47/50  
82/82 [=====] - 5s 60ms/step - loss: 2.5558e-05 - accuracy: 1.0000 - val\_loss: 0.2834 - val\_accuracy: 0.9534  
Epoch 48/50  
82/82 [=====] - 5s 63ms/step - loss: 1.8952e-05 - accuracy: 1.0000 - val\_loss: 0.2814 - val\_accuracy: 0.9559

Epoch 49/50  
82/82 [=====] - 5s 62ms/step - loss: 2.4240e-05 - accuracy: 1.0000 - val\_loss: 0.2830 - val\_accuracy: 0.9534  
Epoch 50/50  
82/82 [=====] - 5s 63ms/step - loss: 1.3388e-05 - accuracy: 1.0000 - val\_loss: 0.2851 - val\_accuracy: 0.9547  
21/21 [=====] - 0s 11ms/step - loss: 0.2096 - accuracy: 0.9541  
Epoch 1/50  
82/82 [=====] - 6s 66ms/step - loss: 0.2363 - accuracy: 0.9110 - val\_loss: 0.5739 - val\_accuracy: 0.7316  
Epoch 2/50  
82/82 [=====] - 5s 64ms/step - loss: 0.1329 - accuracy: 0.9492 - val\_loss: 0.7729 - val\_accuracy: 0.7304  
Epoch 3/50  
82/82 [=====] - 5s 63ms/step - loss: 0.1186 - accuracy: 0.9553 - val\_loss: 0.7280 - val\_accuracy: 0.7304  
Epoch 4/50  
82/82 [=====] - 6s 68ms/step - loss: 0.0988 - accuracy: 0.9637 - val\_loss: 0.3782 - val\_accuracy: 0.9473  
Epoch 5/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0997 - accuracy: 0.9637 - val\_loss: 1.6630 - val\_accuracy: 0.7316  
Epoch 6/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0816 - accuracy: 0.9725 - val\_loss: 0.2807 - val\_accuracy: 0.8909  
Epoch 7/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0614 - accuracy: 0.9782 - val\_loss: 1.6311 - val\_accuracy: 0.7377  
Epoch 8/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0466 - accuracy: 0.9843 - val\_loss: 0.1202 - val\_accuracy: 0.9583  
Epoch 9/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0361 - accuracy: 0.9870 - val\_loss: 0.0979 - val\_accuracy: 0.9571  
Epoch 10/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0347 - accuracy: 0.9885 - val\_loss: 0.1718 - val\_accuracy: 0.9473  
Epoch 11/50  
82/82 [=====] - 5s 66ms/step - loss: 0.0298 - accuracy: 0.9874 - val\_loss: 0.1447 - val\_accuracy: 0.9485  
Epoch 12/50  
82/82 [=====] - 6s 69ms/step - loss: 0.0144 - accuracy: 0.9950 - val\_loss: 0.1921 - val\_accuracy: 0.9338  
Epoch 13/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0677 - accuracy: 0.9771 - val\_loss: 0.2630 - val\_accuracy: 0.9130  
Epoch 14/50  
82/82 [=====] - 5s 66ms/step - loss: 0.0277 - accuracy: 0.9920 - val\_loss: 0.5584 - val\_accuracy: 0.8762  
Epoch 15/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0265 - accuracy: 0.9905 - val\_loss: 0.1541 - val\_accuracy: 0.9436  
Epoch 16/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0128 - accuracy: 0.9966 - val\_loss: 0.1552 - val\_accuracy: 0.9559



Epoch 17/50  
82/82 [=====] - 5s 65ms/step - loss: 0.0151 - accuracy: 0.9950 - val\_loss: 0.1401 - val\_accuracy: 0.9608  
Epoch 18/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0082 - accuracy: 0.9981 - val\_loss: 0.2441 - val\_accuracy: 0.9424  
Epoch 19/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0126 - accuracy: 0.9962 - val\_loss: 0.1559 - val\_accuracy: 0.9620  
Epoch 20/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0226 - accuracy: 0.9897 - val\_loss: 0.1246 - val\_accuracy: 0.9559  
Epoch 21/50  
82/82 [=====] - 6s 67ms/step - loss: 0.0170 - accuracy: 0.9943 - val\_loss: 0.2138 - val\_accuracy: 0.9387  
Epoch 22/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0125 - accuracy: 0.9950 - val\_loss: 0.2550 - val\_accuracy: 0.9363  
Epoch 23/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0070 - accuracy: 0.9981 - val\_loss: 0.2073 - val\_accuracy: 0.9534  
Epoch 24/50  
82/82 [=====] - 5s 63ms/step - loss: 9.7569e-04 - accuracy: 1.0000 - val\_loss: 0.1395 - val\_accuracy: 0.9681  
Epoch 25/50  
82/82 [=====] - 5s 65ms/step - loss: 4.4482e-04 - accuracy: 1.0000 - val\_loss: 0.1467 - val\_accuracy: 0.9657  
Epoch 26/50  
82/82 [=====] - 5s 67ms/step - loss: 2.0446e-04 - accuracy: 1.0000 - val\_loss: 0.1615 - val\_accuracy: 0.9681  
Epoch 27/50  
82/82 [=====] - 5s 62ms/step - loss: 2.0786e-04 - accuracy: 1.0000 - val\_loss: 0.1665 - val\_accuracy: 0.9730  
Epoch 28/50  
82/82 [=====] - 5s 62ms/step - loss: 1.3779e-04 - accuracy: 1.0000 - val\_loss: 0.1675 - val\_accuracy: 0.9706  
Epoch 29/50  
82/82 [=====] - 5s 64ms/step - loss: 8.7228e-05 - accuracy: 1.0000 - val\_loss: 0.1735 - val\_accuracy: 0.9706  
Epoch 30/50  
82/82 [=====] - 5s 64ms/step - loss: 9.7802e-05 - accuracy: 1.0000 - val\_loss: 0.1766 - val\_accuracy: 0.9718  
Epoch 31/50  
82/82 [=====] - 5s 66ms/step - loss: 5.3371e-05 - accuracy: 1.0000 - val\_loss: 0.1770 - val\_accuracy: 0.9718  
Epoch 32/50  
82/82 [=====] - 5s 63ms/step - loss: 6.9935e-05 - accuracy: 1.0000 - val\_loss: 0.1798 - val\_accuracy: 0.9718  
Epoch 33/50  
82/82 [=====] - 5s 62ms/step - loss: 9.3967e-05 - accuracy: 1.0000 - val\_loss: 0.1819 - val\_accuracy: 0.9669  
Epoch 34/50  
82/82 [=====] - 5s 65ms/step - loss: 5.1354e-05 - accuracy: 1.0000 - val\_loss: 0.1823 - val\_accuracy: 0.9718  
Epoch 35/50  
82/82 [=====] - 5s 62ms/step - loss: 4.7641e-05 -

accuracy: 1.0000 - val\_loss: 0.1824 - val\_accuracy: 0.9718  
Epoch 36/50  
82/82 [=====] - 5s 64ms/step - loss: 6.3595e-05 -  
accuracy: 1.0000 - val\_loss: 0.1838 - val\_accuracy: 0.9694  
Epoch 37/50  
82/82 [=====] - 5s 62ms/step - loss: 3.7365e-05 -  
accuracy: 1.0000 - val\_loss: 0.1854 - val\_accuracy: 0.9730  
Epoch 38/50  
82/82 [=====] - 5s 65ms/step - loss: 3.3250e-05 -  
accuracy: 1.0000 - val\_loss: 0.1869 - val\_accuracy: 0.9730  
Epoch 39/50  
82/82 [=====] - 5s 65ms/step - loss: 4.0335e-05 -  
accuracy: 1.0000 - val\_loss: 0.1880 - val\_accuracy: 0.9730  
Epoch 40/50  
82/82 [=====] - 5s 63ms/step - loss: 3.4193e-05 -  
accuracy: 1.0000 - val\_loss: 0.1881 - val\_accuracy: 0.9718  
Epoch 41/50  
82/82 [=====] - 5s 62ms/step - loss: 2.1039e-05 -  
accuracy: 1.0000 - val\_loss: 0.1904 - val\_accuracy: 0.9730  
Epoch 42/50  
82/82 [=====] - 5s 65ms/step - loss: 1.6759e-05 -  
accuracy: 1.0000 - val\_loss: 0.1918 - val\_accuracy: 0.9730  
Epoch 43/50  
82/82 [=====] - 6s 70ms/step - loss: 2.3904e-05 -  
accuracy: 1.0000 - val\_loss: 0.1924 - val\_accuracy: 0.9730  
Epoch 44/50  
82/82 [=====] - 5s 61ms/step - loss: 2.5227e-05 -  
accuracy: 1.0000 - val\_loss: 0.1937 - val\_accuracy: 0.9730  
Epoch 45/50  
82/82 [=====] - 7s 80ms/step - loss: 2.4576e-05 -  
accuracy: 1.0000 - val\_loss: 0.1936 - val\_accuracy: 0.9730  
Epoch 46/50  
82/82 [=====] - 5s 57ms/step - loss: 3.2310e-05 -  
accuracy: 1.0000 - val\_loss: 0.1938 - val\_accuracy: 0.9743  
Epoch 47/50  
82/82 [=====] - 5s 57ms/step - loss: 1.7892e-05 -  
accuracy: 1.0000 - val\_loss: 0.1951 - val\_accuracy: 0.9730  
Epoch 48/50  
82/82 [=====] - 4s 53ms/step - loss: 2.4215e-05 -  
accuracy: 1.0000 - val\_loss: 0.1956 - val\_accuracy: 0.9730  
Epoch 49/50  
82/82 [=====] - 4s 55ms/step - loss: 1.6185e-05 -  
accuracy: 1.0000 - val\_loss: 0.1976 - val\_accuracy: 0.9730  
Epoch 50/50  
82/82 [=====] - 4s 52ms/step - loss: 1.1842e-05 -  
accuracy: 1.0000 - val\_loss: 0.1983 - val\_accuracy: 0.9718  
21/21 [=====] - 0s 9ms/step - loss: 0.2654 - accu  
acy: 0.9602  
Epoch 1/50  
82/82 [=====] - 5s 57ms/step - loss: 0.2473 - accu  
racy: 0.9007 - val\_loss: 0.5752 - val\_accuracy: 0.7304  
Epoch 2/50  
82/82 [=====] - 5s 57ms/step - loss: 0.1507 - accu  
racy: 0.9442 - val\_loss: 0.4381 - val\_accuracy: 0.7966  
Epoch 3/50  
82/82 [=====] - 4s 55ms/step - loss: 0.1328 - accu

racy: 0.9549 - val\_loss: 0.3506 - val\_accuracy: 0.7806  
Epoch 4/50  
82/82 [=====] - 5s 57ms/step - loss: 0.1200 - accu  
racy: 0.9576 - val\_loss: 0.9896 - val\_accuracy: 0.7316  
Epoch 5/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0841 - accu  
racy: 0.9698 - val\_loss: 0.1286 - val\_accuracy: 0.9608  
Epoch 6/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0745 - accu  
racy: 0.9756 - val\_loss: 0.7714 - val\_accuracy: 0.7500  
Epoch 7/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0831 - accu  
racy: 0.9660 - val\_loss: 0.1627 - val\_accuracy: 0.9424  
Epoch 8/50  
82/82 [=====] - 4s 51ms/step - loss: 0.0742 - accu  
racy: 0.9714 - val\_loss: 0.6911 - val\_accuracy: 0.6716  
Epoch 9/50  
82/82 [=====] - 5s 55ms/step - loss: 0.0713 - accu  
racy: 0.9748 - val\_loss: 1.5977 - val\_accuracy: 0.7304  
Epoch 10/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0652 - accu  
racy: 0.9725 - val\_loss: 2.7639 - val\_accuracy: 0.7304  
Epoch 11/50  
82/82 [=====] - 4s 55ms/step - loss: 0.0743 - accu  
racy: 0.9752 - val\_loss: 0.1133 - val\_accuracy: 0.9596  
Epoch 12/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0367 - accu  
racy: 0.9862 - val\_loss: 0.6890 - val\_accuracy: 0.8064  
Epoch 13/50  
82/82 [=====] - 4s 52ms/step - loss: 0.0456 - accu  
racy: 0.9832 - val\_loss: 0.5061 - val\_accuracy: 0.8799  
Epoch 14/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0462 - accu  
racy: 0.9859 - val\_loss: 0.3268 - val\_accuracy: 0.9142  
Epoch 15/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0228 - accu  
racy: 0.9920 - val\_loss: 0.3268 - val\_accuracy: 0.9032  
Epoch 16/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0138 - accu  
racy: 0.9966 - val\_loss: 0.1236 - val\_accuracy: 0.9620  
Epoch 17/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0092 - accu  
racy: 0.9969 - val\_loss: 1.0813 - val\_accuracy: 0.8051  
Epoch 18/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0219 - accu  
racy: 0.9897 - val\_loss: 0.2063 - val\_accuracy: 0.9510  
Epoch 19/50  
82/82 [=====] - 4s 55ms/step - loss: 0.0195 - accu  
racy: 0.9927 - val\_loss: 0.5204 - val\_accuracy: 0.8775  
Epoch 20/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0128 - accu  
racy: 0.9954 - val\_loss: 0.5692 - val\_accuracy: 0.8566  
Epoch 21/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0181 - accu  
racy: 0.9939 - val\_loss: 0.3862 - val\_accuracy: 0.8848  
Epoch 22/50

82/82 [=====] - 4s 55ms/step - loss: 0.0076 - accuracy: 0.9973 - val\_loss: 0.1847 - val\_accuracy: 0.9583  
Epoch 23/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0123 - accuracy: 0.9943 - val\_loss: 1.1583 - val\_accuracy: 0.8395  
Epoch 24/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0164 - accuracy: 0.9927 - val\_loss: 0.1968 - val\_accuracy: 0.9338  
Epoch 25/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0581 - accuracy: 0.9798 - val\_loss: 0.8009 - val\_accuracy: 0.7022  
Epoch 26/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0486 - accuracy: 0.9809 - val\_loss: 1.0253 - val\_accuracy: 0.7966  
Epoch 27/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0246 - accuracy: 0.9916 - val\_loss: 0.1705 - val\_accuracy: 0.9485  
Epoch 28/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0084 - accuracy: 0.9977 - val\_loss: 0.1392 - val\_accuracy: 0.9632  
Epoch 29/50  
82/82 [=====] - 4s 53ms/step - loss: 0.0025 - accuracy: 0.9996 - val\_loss: 0.1883 - val\_accuracy: 0.9461  
Epoch 30/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0010 - accuracy: 1.0000 - val\_loss: 0.2731 - val\_accuracy: 0.9534  
Epoch 31/50  
82/82 [=====] - 5s 56ms/step - loss: 4.3200e-04 - accuracy: 1.0000 - val\_loss: 0.1877 - val\_accuracy: 0.9681  
Epoch 32/50  
82/82 [=====] - 5s 57ms/step - loss: 2.5165e-04 - accuracy: 1.0000 - val\_loss: 0.2137 - val\_accuracy: 0.9632  
Epoch 33/50  
82/82 [=====] - 5s 56ms/step - loss: 1.5685e-04 - accuracy: 1.0000 - val\_loss: 0.1999 - val\_accuracy: 0.9620  
Epoch 34/50  
82/82 [=====] - 4s 55ms/step - loss: 1.3443e-04 - accuracy: 1.0000 - val\_loss: 0.2059 - val\_accuracy: 0.9608  
Epoch 35/50  
82/82 [=====] - 5s 57ms/step - loss: 1.6442e-04 - accuracy: 1.0000 - val\_loss: 0.2078 - val\_accuracy: 0.9632  
Epoch 36/50  
82/82 [=====] - 4s 55ms/step - loss: 1.4785e-04 - accuracy: 1.0000 - val\_loss: 0.2171 - val\_accuracy: 0.9681  
Epoch 37/50  
82/82 [=====] - 4s 54ms/step - loss: 1.2238e-04 - accuracy: 1.0000 - val\_loss: 0.2093 - val\_accuracy: 0.9608  
Epoch 38/50  
82/82 [=====] - 4s 54ms/step - loss: 9.4610e-05 - accuracy: 1.0000 - val\_loss: 0.2118 - val\_accuracy: 0.9632  
Epoch 39/50  
82/82 [=====] - 5s 56ms/step - loss: 5.3927e-05 - accuracy: 1.0000 - val\_loss: 0.2125 - val\_accuracy: 0.9620  
Epoch 40/50  
82/82 [=====] - 5s 58ms/step - loss: 8.1043e-05 - accuracy: 1.0000 - val\_loss: 0.2210 - val\_accuracy: 0.9645

```

Epoch 41/50
82/82 [=====] - 4s 55ms/step - loss: 7.9178e-05 -
accuracy: 1.0000 - val_loss: 0.2136 - val_accuracy: 0.9632
Epoch 42/50
82/82 [=====] - 4s 54ms/step - loss: 4.7166e-05 -
accuracy: 1.0000 - val_loss: 0.2201 - val_accuracy: 0.9632
Epoch 43/50
82/82 [=====] - 5s 57ms/step - loss: 3.4900e-05 -
accuracy: 1.0000 - val_loss: 0.2225 - val_accuracy: 0.9632
Epoch 44/50
82/82 [=====] - 4s 55ms/step - loss: 3.7482e-05 -
accuracy: 1.0000 - val_loss: 0.2307 - val_accuracy: 0.9632
Epoch 45/50
82/82 [=====] - 5s 57ms/step - loss: 3.2110e-05 -
accuracy: 1.0000 - val_loss: 0.2292 - val_accuracy: 0.9632
Epoch 46/50
82/82 [=====] - 5s 56ms/step - loss: 2.6356e-05 -
accuracy: 1.0000 - val_loss: 0.2314 - val_accuracy: 0.9632
Epoch 47/50
82/82 [=====] - 5s 58ms/step - loss: 2.8088e-05 -
accuracy: 1.0000 - val_loss: 0.2312 - val_accuracy: 0.9632
Epoch 48/50
82/82 [=====] - 4s 53ms/step - loss: 2.3200e-05 -
accuracy: 1.0000 - val_loss: 0.2287 - val_accuracy: 0.9632
Epoch 49/50
82/82 [=====] - 4s 54ms/step - loss: 3.1755e-05 -
accuracy: 1.0000 - val_loss: 0.2323 - val_accuracy: 0.9645

```

```
In [118]: save_result('CNN #4', results_train[1], results_test[1], cvs[0], cvs[1], cvs[2], cvs[3], cvs[4])
```

Out[118]:

	model_name	Train Accuracy	Test Accuracy	CV1	CV2	CV3	CV4	CV5	CV_Std	CV_avg
0	CNN #3	1.000	0.953	0.965	0.953	0.960	0.953	0.966	0.007	0.959
0	CNN #2	1.000	0.947	0.953	0.956	0.960	0.953	0.963	0.005	0.957
0	CNN #1	0.953	0.933	0.921	0.940	0.931	0.916	0.945	0.012	0.931
0	CNN #4	1.000	0.950	0.776	0.963	0.954	0.960	0.966	0.083	0.924
0	Initial Model	0.730	0.730	0.925	0.740	0.728	0.709	0.743	0.088	0.769

```
In [119]: predictions = model_4.predict(x = test_images, steps = 10, verbose=0)
```

```
In [120]: pred_check = np.round(predictions)
```

```
In [121]: pred_check = pred_check[:]
pred_check = pred_check.flatten()
pred_check
```

Out[121]: array([1., 1., 1., ..., 0., 0., 0.], dtype=float32)

```
In [122]: test_check = test_labels[:,0]
test_check
```

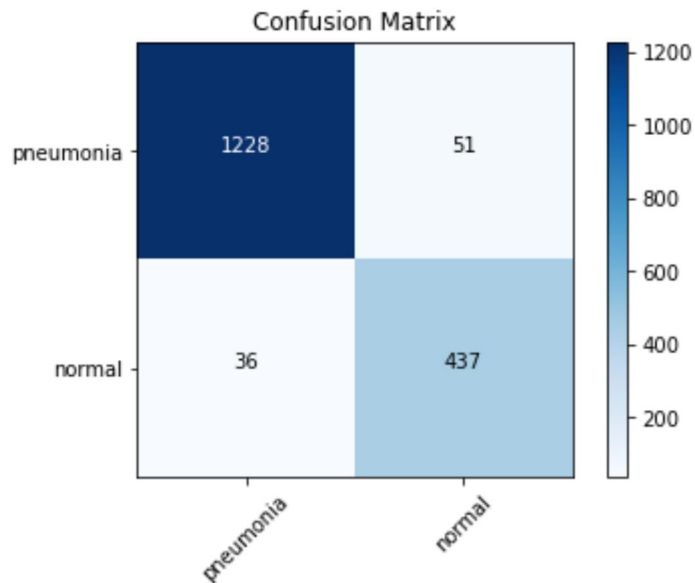
```
Out[122]: array([1., 1., 1., ..., 0., 0., 0.], dtype=float32)
```

```
In [123]: cm = confusion_matrix(y_true=test_check, y_pred=pred_check)
```

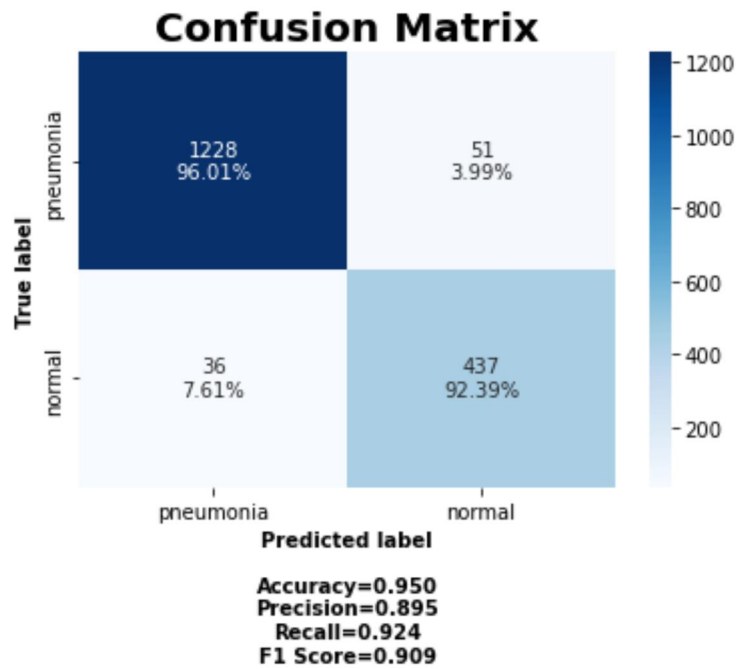
```
In [124]: cm_plot_labels = ['pneumonia', 'normal']
plot_confusion_matrix(cm=cm, classes=cm_plot_labels, title='Confusion Matrix')
```

Confusion matrix, without normalization

```
[[1228  51]
 [ 36 437]]
```



```
In [125]: cm_plot_labels = ['pneumonia', 'normal']  
make_confusion_matrix(cm, categories = cm_plot_labels, title='Confusion Matrix')
```



## CNN Model 5: Model 3 with added layer

After observing how the first five models ran, CNN #2 was the best model due to low standard deviation for the cross validation and high test and train accuracy. I will try adding dropout to help the little bit of overtraining that is occurring

```

In [126]: model 6 = model s. Sequential ()

model 6.add(layers.Conv2D(32, (3, 3), activation='relu', input_shape=(64, 64,
3)))
model 6.add(layers.MaxPooling2D((2, 2)))

model 6.add(layers.Conv2D(32, (4, 4), activation='relu'))
model 6.add(BatchNormalization())
model 6.add(layers.MaxPooling2D((2, 2)))

model 6.add(layers.Conv2D(64, (3, 3), activation='relu'))
model 6.add(BatchNormalization())
model 6.add(layers.MaxPooling2D((2, 2)))

model 6.add(layers.Conv2D(96, (3, 3), activation='relu', padding='same')) #
new
model 6.add(BatchNormalization()) # n
ew
model 6.add(Dropout(0.1)) # n
ew
model 6.add(layers.MaxPooling2D((2, 2)))
# new

model 6.add(layers.Conv2D(128, (3, 3), activation='relu', padding='same'))
model 6.add(BatchNormalization())
model 6.add(layers.MaxPooling2D((2, 2)))

model 6.add(layers.Flatten())
model 6.add(layers.Dense(64, activation='relu'))
model 6.add(Dropout(0.1))
model 6.add(layers.Dense(1, activation='sigmoid'))

model 6.compile(loss='binary_crossentropy',
                optimizer="adam",
                metrics=['accuracy'])

```



[illegible]

Epoch 1/50  
103/103 [=====] - 6s 58ms/step - loss: 0.2112 - accuracy: 0.9105 - val\_loss: 1.2231 - val\_accuracy: 0.7304

Epoch 2/50  
103/103 [=====] - 6s 55ms/step - loss: 0.1570 - accuracy: 0.9459 - val\_loss: 1.9283 - val\_accuracy: 0.7304

Epoch 3/50  
103/103 [=====] - 6s 55ms/step - loss: 0.1382 - accuracy: 0.9517 - val\_loss: 2.6658 - val\_accuracy: 0.7304

Epoch 4/50  
103/103 [=====] - 6s 55ms/step - loss: 0.1096 - accuracy: 0.9554 - val\_loss: 0.1401 - val\_accuracy: 0.9485

Epoch 5/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0883 - accuracy: 0.9667 - val\_loss: 0.1153 - val\_accuracy: 0.9620

Epoch 6/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0893 - accuracy: 0.9664 - val\_loss: 0.2954 - val\_accuracy: 0.8615

Epoch 7/50  
103/103 [=====] - 6s 55ms/step - loss: 0.0845 - accuracy: 0.9667 - val\_loss: 0.3719 - val\_accuracy: 0.8309

Epoch 8/50  
103/103 [=====] - 6s 59ms/step - loss: 0.0778 - accuracy: 0.9731 - val\_loss: 0.8504 - val\_accuracy: 0.7426

Epoch 9/50  
103/103 [=====] - 6s 55ms/step - loss: 0.0767 - accuracy: 0.9682 - val\_loss: 1.6440 - val\_accuracy: 0.4375

Epoch 10/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0810 - accuracy: 0.9725 - val\_loss: 0.4331 - val\_accuracy: 0.8750

Epoch 11/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0568 - accuracy: 0.9807 - val\_loss: 0.3989 - val\_accuracy: 0.8750

Epoch 12/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0483 - accuracy: 0.9811 - val\_loss: 0.1430 - val\_accuracy: 0.9534

Epoch 13/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0290 - accuracy: 0.9893 - val\_loss: 0.1508 - val\_accuracy: 0.9534

Epoch 14/50  
103/103 [=====] - 5s 53ms/step - loss: 0.0275 - accuracy: 0.9905 - val\_loss: 0.1015 - val\_accuracy: 0.9632

Epoch 15/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0403 - accuracy: 0.9850 - val\_loss: 0.5956 - val\_accuracy: 0.8284

Epoch 16/50  
103/103 [=====] - 6s 55ms/step - loss: 0.0273 - accuracy: 0.9881 - val\_loss: 0.4143 - val\_accuracy: 0.8775

Epoch 17/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0342 - accuracy: 0.9869 - val\_loss: 0.1245 - val\_accuracy: 0.9632

Epoch 18/50  
103/103 [=====] - 6s 60ms/step - loss: 0.0308 - accuracy: 0.9881 - val\_loss: 0.2081 - val\_accuracy: 0.9338

Epoch 19/50  
103/103 [=====] - 6s 58ms/step - loss: 0.0288 - ac

curacy: 0.9899 - val\_loss: 0.5740 - val\_accuracy: 0.8554  
Epoch 20/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0300 - ac  
curacy: 0.9902 - val\_loss: 0.3089 - val\_accuracy: 0.9338  
Epoch 21/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0218 - ac  
curacy: 0.9921 - val\_loss: 0.1679 - val\_accuracy: 0.9559  
Epoch 22/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0136 - ac  
curacy: 0.9942 - val\_loss: 0.1276 - val\_accuracy: 0.9657  
Epoch 23/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0350 - ac  
curacy: 0.9856 - val\_loss: 0.4882 - val\_accuracy: 0.8505  
Epoch 24/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0498 - ac  
curacy: 0.9817 - val\_loss: 0.9944 - val\_accuracy: 0.8088  
Epoch 25/50  
103/103 [=====] - 6s 58ms/step - loss: 0.0374 - ac  
curacy: 0.9875 - val\_loss: 0.4272 - val\_accuracy: 0.8885  
Epoch 26/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0255 - ac  
curacy: 0.9917 - val\_loss: 0.4889 - val\_accuracy: 0.8419  
Epoch 27/50  
103/103 [=====] - 6s 58ms/step - loss: 0.0128 - ac  
curacy: 0.9966 - val\_loss: 0.1471 - val\_accuracy: 0.9657  
Epoch 28/50  
103/103 [=====] - 6s 58ms/step - loss: 0.0141 - ac  
curacy: 0.9948 - val\_loss: 0.1892 - val\_accuracy: 0.9436  
Epoch 29/50  
103/103 [=====] - 6s 55ms/step - loss: 0.0139 - ac  
curacy: 0.9951 - val\_loss: 0.2468 - val\_accuracy: 0.9240  
Epoch 30/50  
103/103 [=====] - 6s 59ms/step - loss: 0.0215 - ac  
curacy: 0.9911 - val\_loss: 0.1467 - val\_accuracy: 0.9583  
Epoch 31/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0138 - ac  
curacy: 0.9951 - val\_loss: 1.5727 - val\_accuracy: 0.6238  
Epoch 32/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0079 - ac  
curacy: 0.9976 - val\_loss: 0.3685 - val\_accuracy: 0.9387  
Epoch 33/50  
103/103 [=====] - 6s 55ms/step - loss: 0.0035 - ac  
curacy: 0.9988 - val\_loss: 0.1970 - val\_accuracy: 0.9620  
Epoch 34/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0042 - ac  
curacy: 0.9988 - val\_loss: 0.1916 - val\_accuracy: 0.9645  
Epoch 35/50  
103/103 [=====] - 6s 56ms/step - loss: 0.0073 - ac  
curacy: 0.9966 - val\_loss: 0.4649 - val\_accuracy: 0.8873  
Epoch 36/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0232 - ac  
curacy: 0.9914 - val\_loss: 3.4044 - val\_accuracy: 0.7304  
Epoch 37/50  
103/103 [=====] - 6s 57ms/step - loss: 0.0104 - ac  
curacy: 0.9976 - val\_loss: 0.2002 - val\_accuracy: 0.9363  
Epoch 38/50

```

103/103 [=====] - 6s 57ms/step - loss: 0.0147 - ac
curacy: 0.9951 - val_loss: 0.1933 - val_accuracy: 0.9596
Epoch 39/50
103/103 [=====] - 6s 58ms/step - loss: 0.0127 - ac
curacy: 0.9951 - val_loss: 0.5799 - val_accuracy: 0.8493
Epoch 40/50
103/103 [=====] - 6s 55ms/step - loss: 0.0194 - ac
curacy: 0.9933 - val_loss: 0.2030 - val_accuracy: 0.9449
Epoch 41/50
103/103 [=====] - 6s 56ms/step - loss: 0.0165 - ac
curacy: 0.9942 - val_loss: 0.3196 - val_accuracy: 0.9301
Epoch 42/50
103/103 [=====] - 6s 55ms/step - loss: 0.0113 - ac
curacy: 0.9960 - val_loss: 0.1610 - val_accuracy: 0.9583
Epoch 43/50
103/103 [=====] - 6s 55ms/step - loss: 0.0097 - ac
curacy: 0.9966 - val_loss: 0.6392 - val_accuracy: 0.8615
Epoch 44/50
103/103 [=====] - 6s 54ms/step - loss: 0.0083 - ac
curacy: 0.9969 - val_loss: 0.1637 - val_accuracy: 0.9657
Epoch 45/50
103/103 [=====] - 6s 56ms/step - loss: 0.0054 - ac
curacy: 0.9982 - val_loss: 0.4665 - val_accuracy: 0.9216
Epoch 46/50
103/103 [=====] - 6s 55ms/step - loss: 0.0050 - ac
curacy: 0.9979 - val_loss: 0.3424 - val_accuracy: 0.9301
Epoch 47/50
103/103 [=====] - 6s 56ms/step - loss: 0.0236 - ac
curacy: 0.9911 - val_loss: 0.8578 - val_accuracy: 0.8064
Epoch 48/50
103/103 [=====] - 5s 52ms/step - loss: 0.0120 - ac
curacy: 0.9966 - val_loss: 0.1479 - val_accuracy: 0.9669
Epoch 49/50
103/103 [=====] - 6s 56ms/step - loss: 0.0012 - ac
curacy: 0.9997 - val_loss: 0.1643 - val_accuracy: 0.9657
Epoch 50/50
103/103 [=====] - 6s 57ms/step - loss: 8.0470e-04
- accuracy: 1.0000 - val_loss: 0.1661 - val_accuracy: 0.9645

```

```
In [128]: results_train = model6.evaluate(train_images, train_y)
```

```

103/103 [=====] - 1s 10ms/step - loss: 4.3002e-04
- accuracy: 1.0000

```

```
In [129]: results_test = model6.evaluate(test_images, test_y)
```

```

55/55 [=====] - 1s 10ms/step - loss: 0.2580 - accu
racy: 0.9555

```

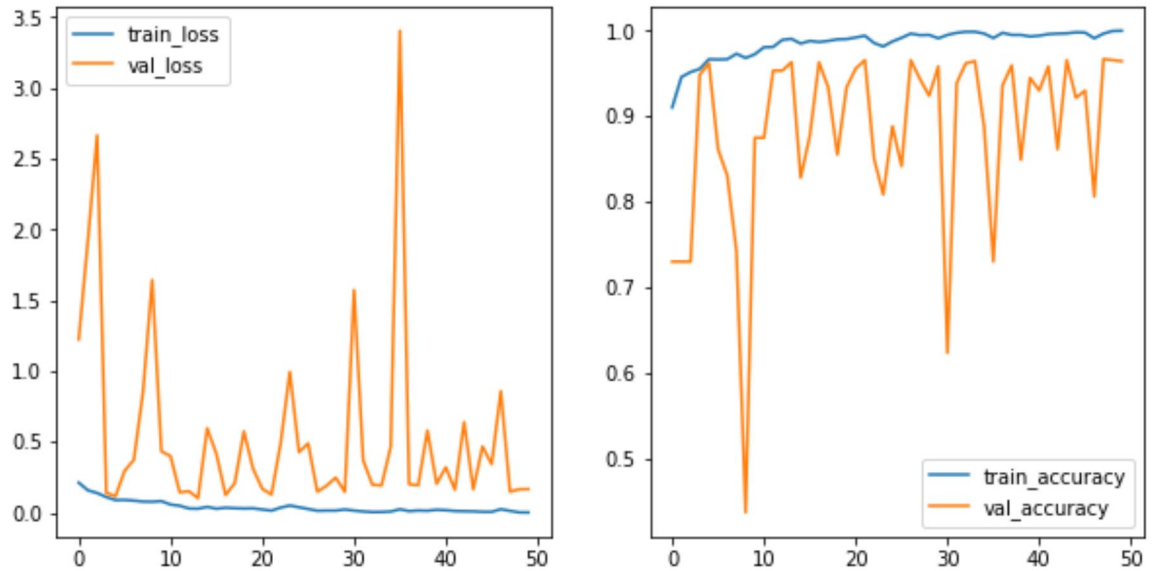
```

In [130]: train_loss = history.history['loss']
train_acc = history.history['accuracy']
val_loss = history.history['val_loss']
val_acc = history.history['val_accuracy']

fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(10, 5))
sns.lineplot(x=history.epoch, y=train_loss, ax=ax1, label='train_loss')
sns.lineplot(x=history.epoch, y=train_acc, ax=ax2, label='train_accuracy')
sns.lineplot(x=history.epoch, y=val_loss, ax=ax1, label='val_loss')
sns.lineplot(x=history.epoch, y=val_acc, ax=ax2, label='val_accuracy')

```

Out[130]: <AxesSubplot: >



```
In [131]: def build_cnn6():  
    model_6 = models.Sequential()  
  
    model_6.add(layers.Conv2D(32, (3, 3), activation='relu', input_shape=(64,  
    , 64, 3)))  
    model_6.add(layers.MaxPooling2D((2, 2)))  
  
    model_6.add(layers.Conv2D(32, (4, 4), activation='relu'))  
    model_6.add(BatchNormalization())  
    model_6.add(layers.MaxPooling2D((2, 2)))  
  
    model_6.add(layers.Conv2D(64, (3, 3), activation='relu'))  
    model_6.add(BatchNormalization())  
    model_6.add(layers.MaxPooling2D((2, 2)))  
  
    model_6.add(layers.Conv2D(96, (3, 3), activation='relu', padding='same'  
    )) # new  
    model_6.add(BatchNormalization())  
    # new  
    model_6.add(Dropout(0.1))  
    # new  
    model_6.add(layers.MaxPooling2D((2, 2)))  
    # new  
  
    model_6.add(layers.Conv2D(128, (3, 3), activation='relu', padding='same'  
    ))  
    model_6.add(BatchNormalization())  
    model_6.add(layers.MaxPooling2D((2, 2)))  
  
    model_6.add(layers.Flatten())  
    model_6.add(layers.Dense(64, activation='relu'))  
    model_6.add(Dropout(0.1))  
    model_6.add(layers.Dense(1, activation='sigmoid'))  
  
    model_6.compile(loss='binary_crossentropy',  
                    optimizer="adam",  
                    metrics=['accuracy'])  
  
    return model_6
```

[illegible]

```
In [133]: cvs = cross_val_score(keras_model6, train_images , train_y, cv=5)
```

Epoch 1/50  
82/82 [=====] - 6s 61ms/step - loss: 0.2412 - accuracy: 0.9052 - val\_loss: 0.6171 - val\_accuracy: 0.7304  
Epoch 2/50  
82/82 [=====] - 5s 60ms/step - loss: 0.1525 - accuracy: 0.9457 - val\_loss: 0.7723 - val\_accuracy: 0.7304  
Epoch 3/50  
82/82 [=====] - 5s 60ms/step - loss: 0.1233 - accuracy: 0.9557 - val\_loss: 0.6482 - val\_accuracy: 0.7304  
Epoch 4/50  
82/82 [=====] - 5s 58ms/step - loss: 0.1045 - accuracy: 0.9626 - val\_loss: 0.8684 - val\_accuracy: 0.7304  
Epoch 5/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0868 - accuracy: 0.9652 - val\_loss: 0.8161 - val\_accuracy: 0.5012  
Epoch 6/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0744 - accuracy: 0.9729 - val\_loss: 0.8876 - val\_accuracy: 0.7647  
Epoch 7/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0775 - accuracy: 0.9694 - val\_loss: 0.2040 - val\_accuracy: 0.9449  
Epoch 8/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0827 - accuracy: 0.9702 - val\_loss: 0.4030 - val\_accuracy: 0.8762  
Epoch 9/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0534 - accuracy: 0.9813 - val\_loss: 1.5598 - val\_accuracy: 0.7341  
Epoch 10/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0685 - accuracy: 0.9748 - val\_loss: 0.4202 - val\_accuracy: 0.8419  
Epoch 11/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0388 - accuracy: 0.9862 - val\_loss: 0.4124 - val\_accuracy: 0.8370  
Epoch 12/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0272 - accuracy: 0.9904 - val\_loss: 0.2070 - val\_accuracy: 0.9252  
Epoch 13/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0453 - accuracy: 0.9832 - val\_loss: 0.1747 - val\_accuracy: 0.9338  
Epoch 14/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0415 - accuracy: 0.9851 - val\_loss: 1.4600 - val\_accuracy: 0.7451  
Epoch 15/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0303 - accuracy: 0.9897 - val\_loss: 0.1690 - val\_accuracy: 0.9449  
Epoch 16/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0360 - accuracy: 0.9870 - val\_loss: 0.3106 - val\_accuracy: 0.8983  
Epoch 17/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0219 - accuracy: 0.9931 - val\_loss: 0.2852 - val\_accuracy: 0.9203  
Epoch 18/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0272 - accuracy: 0.9908 - val\_loss: 0.3297 - val\_accuracy: 0.9118  
Epoch 19/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0257 - accuracy:



racy: 0.9912 - val\_loss: 0.3143 - val\_accuracy: 0.9203  
Epoch 20/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0140 - accu  
racy: 0.9969 - val\_loss: 0.1783 - val\_accuracy: 0.9485  
Epoch 21/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0196 - accu  
racy: 0.9935 - val\_loss: 2.6210 - val\_accuracy: 0.7561  
Epoch 22/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0242 - accu  
racy: 0.9916 - val\_loss: 1.3819 - val\_accuracy: 0.7414  
Epoch 23/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0299 - accu  
racy: 0.9897 - val\_loss: 0.5557 - val\_accuracy: 0.8713  
Epoch 24/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0194 - accu  
racy: 0.9920 - val\_loss: 0.4885 - val\_accuracy: 0.8186  
Epoch 25/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0210 - accu  
racy: 0.9939 - val\_loss: 0.8582 - val\_accuracy: 0.8284  
Epoch 26/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0140 - accu  
racy: 0.9954 - val\_loss: 0.1538 - val\_accuracy: 0.9669  
Epoch 27/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0122 - accu  
racy: 0.9958 - val\_loss: 0.1801 - val\_accuracy: 0.9534  
Epoch 28/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0022 - accu  
racy: 0.9996 - val\_loss: 0.2296 - val\_accuracy: 0.9608  
Epoch 29/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0047 - accu  
racy: 0.9973 - val\_loss: 0.1998 - val\_accuracy: 0.9608  
Epoch 30/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0114 - accu  
racy: 0.9962 - val\_loss: 0.1311 - val\_accuracy: 0.9657  
Epoch 31/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0281 - accu  
racy: 0.9912 - val\_loss: 0.2679 - val\_accuracy: 0.9056  
Epoch 32/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0157 - accu  
racy: 0.9950 - val\_loss: 0.2940 - val\_accuracy: 0.9461  
Epoch 33/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0036 - accu  
racy: 0.9985 - val\_loss: 0.1682 - val\_accuracy: 0.9461  
Epoch 34/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0099 - accu  
racy: 0.9966 - val\_loss: 0.2818 - val\_accuracy: 0.9142  
Epoch 35/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0149 - accu  
racy: 0.9950 - val\_loss: 0.3531 - val\_accuracy: 0.9179  
Epoch 36/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0177 - accu  
racy: 0.9935 - val\_loss: 0.2159 - val\_accuracy: 0.9387  
Epoch 37/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0170 - accu  
racy: 0.9943 - val\_loss: 0.1765 - val\_accuracy: 0.9485  
Epoch 38/50

82/82 [=====] - 5s 61ms/step - loss: 0.0060 - accuracy: 0.9981 - val\_loss: 0.1642 - val\_accuracy: 0.9681  
Epoch 39/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0046 - accuracy: 0.9985 - val\_loss: 0.8693 - val\_accuracy: 0.8652  
Epoch 40/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0083 - accuracy: 0.9966 - val\_loss: 0.2256 - val\_accuracy: 0.9547  
Epoch 41/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0027 - accuracy: 0.9992 - val\_loss: 0.2361 - val\_accuracy: 0.9473  
Epoch 42/50  
82/82 [=====] - 5s 59ms/step - loss: 8.0993e-04 - accuracy: 1.0000 - val\_loss: 0.2027 - val\_accuracy: 0.9620  
Epoch 43/50  
82/82 [=====] - 5s 57ms/step - loss: 3.6418e-04 - accuracy: 1.0000 - val\_loss: 0.1988 - val\_accuracy: 0.9681  
Epoch 44/50  
82/82 [=====] - 5s 62ms/step - loss: 2.8583e-04 - accuracy: 1.0000 - val\_loss: 0.1954 - val\_accuracy: 0.9669  
Epoch 45/50  
82/82 [=====] - 5s 59ms/step - loss: 9.5665e-05 - accuracy: 1.0000 - val\_loss: 0.1871 - val\_accuracy: 0.9718  
Epoch 46/50  
82/82 [=====] - 5s 57ms/step - loss: 1.2715e-04 - accuracy: 1.0000 - val\_loss: 0.1929 - val\_accuracy: 0.9706  
Epoch 47/50  
82/82 [=====] - 5s 60ms/step - loss: 5.1124e-05 - accuracy: 1.0000 - val\_loss: 0.1952 - val\_accuracy: 0.9706  
Epoch 48/50  
82/82 [=====] - 5s 59ms/step - loss: 3.3758e-05 - accuracy: 1.0000 - val\_loss: 0.1980 - val\_accuracy: 0.9706  
Epoch 49/50  
82/82 [=====] - 5s 58ms/step - loss: 7.1864e-05 - accuracy: 1.0000 - val\_loss: 0.2016 - val\_accuracy: 0.9743  
Epoch 50/50  
82/82 [=====] - 5s 61ms/step - loss: 3.4748e-05 - accuracy: 1.0000 - val\_loss: 0.2045 - val\_accuracy: 0.9694  
21/21 [=====] - 0s 10ms/step - loss: 0.2873 - accuracy: 0.9618  
Epoch 1/50  
82/82 [=====] - 5s 60ms/step - loss: 0.2445 - accuracy: 0.9102 - val\_loss: 0.8410 - val\_accuracy: 0.7304  
Epoch 2/50  
82/82 [=====] - 5s 62ms/step - loss: 0.1542 - accuracy: 0.9461 - val\_loss: 1.0326 - val\_accuracy: 0.7304  
Epoch 3/50  
82/82 [=====] - 5s 56ms/step - loss: 0.1339 - accuracy: 0.9538 - val\_loss: 0.5782 - val\_accuracy: 0.7439  
Epoch 4/50  
82/82 [=====] - 5s 57ms/step - loss: 0.1166 - accuracy: 0.9572 - val\_loss: 1.6657 - val\_accuracy: 0.7304  
Epoch 5/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0981 - accuracy: 0.9645 - val\_loss: 1.4409 - val\_accuracy: 0.7316  
Epoch 6/50

82/82 [=====] - 5s 59ms/step - loss: 0.1054 - accuracy: 0.9622 - val\_loss: 0.2012 - val\_accuracy: 0.9485  
Epoch 7/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0922 - accuracy: 0.9668 - val\_loss: 0.3281 - val\_accuracy: 0.8836  
Epoch 8/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0776 - accuracy: 0.9717 - val\_loss: 0.6258 - val\_accuracy: 0.7451  
Epoch 9/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0765 - accuracy: 0.9717 - val\_loss: 0.2113 - val\_accuracy: 0.9252  
Epoch 10/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0460 - accuracy: 0.9862 - val\_loss: 0.4233 - val\_accuracy: 0.8125  
Epoch 11/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0585 - accuracy: 0.9801 - val\_loss: 3.8455 - val\_accuracy: 0.7304  
Epoch 12/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0581 - accuracy: 0.9782 - val\_loss: 0.6973 - val\_accuracy: 0.7328  
Epoch 13/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0481 - accuracy: 0.9805 - val\_loss: 0.1175 - val\_accuracy: 0.9547  
Epoch 14/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0464 - accuracy: 0.9824 - val\_loss: 0.2053 - val\_accuracy: 0.9240  
Epoch 15/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0339 - accuracy: 0.9874 - val\_loss: 1.3123 - val\_accuracy: 0.7439  
Epoch 16/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0481 - accuracy: 0.9828 - val\_loss: 0.1615 - val\_accuracy: 0.9498  
Epoch 17/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0818 - accuracy: 0.9671 - val\_loss: 2.4563 - val\_accuracy: 0.7304  
Epoch 18/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0495 - accuracy: 0.9817 - val\_loss: 0.5975 - val\_accuracy: 0.7929  
Epoch 19/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0321 - accuracy: 0.9897 - val\_loss: 0.2906 - val\_accuracy: 0.9007  
Epoch 20/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0273 - accuracy: 0.9904 - val\_loss: 0.2114 - val\_accuracy: 0.9179  
Epoch 21/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0171 - accuracy: 0.9947 - val\_loss: 0.1779 - val\_accuracy: 0.9559  
Epoch 22/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0209 - accuracy: 0.9920 - val\_loss: 0.1736 - val\_accuracy: 0.9620  
Epoch 23/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0358 - accuracy: 0.9855 - val\_loss: 0.1388 - val\_accuracy: 0.9522  
Epoch 24/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0149 - accuracy: 0.9958 - val\_loss: 0.2714 - val\_accuracy: 0.9424

Epoch 25/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0316 - accuracy: 0.9901 - val\_loss: 0.4438 - val\_accuracy: 0.8627  
Epoch 26/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0437 - accuracy: 0.9851 - val\_loss: 2.1732 - val\_accuracy: 0.7304  
Epoch 27/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0167 - accuracy: 0.9939 - val\_loss: 0.2633 - val\_accuracy: 0.9240  
Epoch 28/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0133 - accuracy: 0.9950 - val\_loss: 0.9561 - val\_accuracy: 0.7194  
Epoch 29/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0255 - accuracy: 0.9901 - val\_loss: 0.5310 - val\_accuracy: 0.8015  
Epoch 30/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0269 - accuracy: 0.9904 - val\_loss: 0.1430 - val\_accuracy: 0.9657  
Epoch 31/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0162 - accuracy: 0.9947 - val\_loss: 0.2770 - val\_accuracy: 0.9069  
Epoch 32/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0082 - accuracy: 0.9969 - val\_loss: 0.2887 - val\_accuracy: 0.9387  
Epoch 33/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0093 - accuracy: 0.9958 - val\_loss: 0.1516 - val\_accuracy: 0.9596  
Epoch 34/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0179 - accuracy: 0.9935 - val\_loss: 0.7683 - val\_accuracy: 0.8995  
Epoch 35/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0169 - accuracy: 0.9931 - val\_loss: 0.5009 - val\_accuracy: 0.8971  
Epoch 36/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0146 - accuracy: 0.9950 - val\_loss: 0.2479 - val\_accuracy: 0.9265  
Epoch 37/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0132 - accuracy: 0.9947 - val\_loss: 0.1689 - val\_accuracy: 0.9387  
Epoch 38/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0204 - accuracy: 0.9931 - val\_loss: 0.3251 - val\_accuracy: 0.9265  
Epoch 39/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0080 - accuracy: 0.9977 - val\_loss: 0.2968 - val\_accuracy: 0.9289  
Epoch 40/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0116 - accuracy: 0.9969 - val\_loss: 0.1768 - val\_accuracy: 0.9596  
Epoch 41/50  
82/82 [=====] - 4s 54ms/step - loss: 0.0096 - accuracy: 0.9962 - val\_loss: 0.4448 - val\_accuracy: 0.8750  
Epoch 42/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0082 - accuracy: 0.9969 - val\_loss: 2.0682 - val\_accuracy: 0.7843  
Epoch 43/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0175 - accuracy:

racy: 0.9958 - val\_loss: 0.1857 - val\_accuracy: 0.9620  
Epoch 44/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0158 - accu  
racy: 0.9947 - val\_loss: 0.1847 - val\_accuracy: 0.9596  
Epoch 45/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0030 - accu  
racy: 0.9992 - val\_loss: 0.2807 - val\_accuracy: 0.9559  
Epoch 46/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0039 - accu  
racy: 0.9989 - val\_loss: 0.2136 - val\_accuracy: 0.9620  
Epoch 47/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0112 - accu  
racy: 0.9962 - val\_loss: 1.8520 - val\_accuracy: 0.5882  
Epoch 48/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0061 - accu  
racy: 0.9981 - val\_loss: 2.0030 - val\_accuracy: 0.7721  
Epoch 49/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0056 - accu  
racy: 0.9989 - val\_loss: 0.5887 - val\_accuracy: 0.9020  
Epoch 50/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0097 - accu  
racy: 0.9969 - val\_loss: 0.1953 - val\_accuracy: 0.9583  
21/21 [=====] - 0s 10ms/step - loss: 0.1915 - accu  
racy: 0.9618  
Epoch 1/50  
82/82 [=====] - 5s 60ms/step - loss: 0.2119 - accu  
racy: 0.9133 - val\_loss: 0.6276 - val\_accuracy: 0.7304  
Epoch 2/50  
82/82 [=====] - 5s 57ms/step - loss: 0.1516 - accu  
racy: 0.9461 - val\_loss: 0.8453 - val\_accuracy: 0.7304  
Epoch 3/50  
82/82 [=====] - 5s 60ms/step - loss: 0.1220 - accu  
racy: 0.9618 - val\_loss: 0.9819 - val\_accuracy: 0.7304  
Epoch 4/50  
82/82 [=====] - 5s 56ms/step - loss: 0.1136 - accu  
racy: 0.9572 - val\_loss: 0.6314 - val\_accuracy: 0.5478  
Epoch 5/50  
82/82 [=====] - 5s 59ms/step - loss: 0.1035 - accu  
racy: 0.9652 - val\_loss: 0.3815 - val\_accuracy: 0.8064  
Epoch 6/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0781 - accu  
racy: 0.9721 - val\_loss: 0.1821 - val\_accuracy: 0.9228  
Epoch 7/50  
82/82 [=====] - 5s 60ms/step - loss: 0.1023 - accu  
racy: 0.9584 - val\_loss: 0.1647 - val\_accuracy: 0.9387  
Epoch 8/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0814 - accu  
racy: 0.9702 - val\_loss: 0.1156 - val\_accuracy: 0.9596  
Epoch 9/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0621 - accu  
racy: 0.9801 - val\_loss: 0.1283 - val\_accuracy: 0.9534  
Epoch 10/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0672 - accu  
racy: 0.9775 - val\_loss: 0.4540 - val\_accuracy: 0.8419  
Epoch 11/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0414 - accu

racy: 0.9847 - val\_loss: 0.3068 - val\_accuracy: 0.8922  
Epoch 12/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0365 - accu  
racy: 0.9866 - val\_loss: 1.4379 - val\_accuracy: 0.7304  
Epoch 13/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0411 - accu  
racy: 0.9855 - val\_loss: 0.5353 - val\_accuracy: 0.8333  
Epoch 14/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0380 - accu  
racy: 0.9862 - val\_loss: 0.4590 - val\_accuracy: 0.8370  
Epoch 15/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0400 - accu  
racy: 0.9847 - val\_loss: 0.1863 - val\_accuracy: 0.9363  
Epoch 16/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0328 - accu  
racy: 0.9870 - val\_loss: 0.1279 - val\_accuracy: 0.9657  
Epoch 17/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0233 - accu  
racy: 0.9908 - val\_loss: 1.4712 - val\_accuracy: 0.7549  
Epoch 18/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0350 - accu  
racy: 0.9859 - val\_loss: 0.2104 - val\_accuracy: 0.9632  
Epoch 19/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0203 - accu  
racy: 0.9924 - val\_loss: 0.1415 - val\_accuracy: 0.9669  
Epoch 20/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0098 - accu  
racy: 0.9962 - val\_loss: 0.2194 - val\_accuracy: 0.9375  
Epoch 21/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0159 - accu  
racy: 0.9950 - val\_loss: 0.6446 - val\_accuracy: 0.8909  
Epoch 22/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0300 - accu  
racy: 0.9924 - val\_loss: 0.2001 - val\_accuracy: 0.9485  
Epoch 23/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0141 - accu  
racy: 0.9950 - val\_loss: 0.1468 - val\_accuracy: 0.9473  
Epoch 24/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0087 - accu  
racy: 0.9977 - val\_loss: 0.6114 - val\_accuracy: 0.8051  
Epoch 25/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0039 - accu  
racy: 0.9996 - val\_loss: 0.1617 - val\_accuracy: 0.9681  
Epoch 26/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0016 - accu  
racy: 0.9996 - val\_loss: 0.2225 - val\_accuracy: 0.9571  
Epoch 27/50  
82/82 [=====] - 5s 55ms/step - loss: 0.0132 - accu  
racy: 0.9943 - val\_loss: 0.2054 - val\_accuracy: 0.9461  
Epoch 28/50  
82/82 [=====] - 4s 55ms/step - loss: 0.0188 - accu  
racy: 0.9947 - val\_loss: 0.2368 - val\_accuracy: 0.9191  
Epoch 29/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0180 - accu  
racy: 0.9924 - val\_loss: 0.3642 - val\_accuracy: 0.9069  
Epoch 30/50

82/82 [=====] - 5s 57ms/step - loss: 0.0260 - accuracy: 0.9920 - val\_loss: 1.1273 - val\_accuracy: 0.8321  
Epoch 31/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0130 - accuracy: 0.9954 - val\_loss: 0.1725 - val\_accuracy: 0.9657  
Epoch 32/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0092 - accuracy: 0.9966 - val\_loss: 0.1786 - val\_accuracy: 0.9510  
Epoch 33/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0286 - accuracy: 0.9889 - val\_loss: 0.1910 - val\_accuracy: 0.9473  
Epoch 34/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0211 - accuracy: 0.9931 - val\_loss: 0.2136 - val\_accuracy: 0.9534  
Epoch 35/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0090 - accuracy: 0.9973 - val\_loss: 0.3666 - val\_accuracy: 0.8909  
Epoch 36/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0035 - accuracy: 0.9992 - val\_loss: 0.3763 - val\_accuracy: 0.9265  
Epoch 37/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0058 - accuracy: 0.9973 - val\_loss: 3.4890 - val\_accuracy: 0.7304  
Epoch 38/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0379 - accuracy: 0.9836 - val\_loss: 0.4607 - val\_accuracy: 0.8713  
Epoch 39/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0495 - accuracy: 0.9824 - val\_loss: 0.2361 - val\_accuracy: 0.8971  
Epoch 40/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0317 - accuracy: 0.9870 - val\_loss: 0.2003 - val\_accuracy: 0.9265  
Epoch 41/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0179 - accuracy: 0.9943 - val\_loss: 0.1646 - val\_accuracy: 0.9620  
Epoch 42/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0062 - accuracy: 0.9985 - val\_loss: 0.1652 - val\_accuracy: 0.9571  
Epoch 43/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0085 - accuracy: 0.9973 - val\_loss: 0.1902 - val\_accuracy: 0.9547  
Epoch 44/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0034 - accuracy: 0.9989 - val\_loss: 0.1426 - val\_accuracy: 0.9645  
Epoch 45/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0037 - accuracy: 0.9989 - val\_loss: 0.1523 - val\_accuracy: 0.9681  
Epoch 46/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0231 - accuracy: 0.9912 - val\_loss: 0.6940 - val\_accuracy: 0.8370  
Epoch 47/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0115 - accuracy: 0.9954 - val\_loss: 0.1528 - val\_accuracy: 0.9657  
Epoch 48/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0214 - accuracy: 0.9935 - val\_loss: 1.0487 - val\_accuracy: 0.7782

Epoch 49/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0171 - accuracy: 0.9943 - val\_loss: 0.1135 - val\_accuracy: 0.9645  
Epoch 50/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0079 - accuracy: 0.9973 - val\_loss: 0.2055 - val\_accuracy: 0.9547  
21/21 [=====] - 0s 10ms/step - loss: 0.1648 - accuracy: 0.9526  
Epoch 1/50  
82/82 [=====] - 5s 60ms/step - loss: 0.2212 - accuracy: 0.9160 - val\_loss: 0.6558 - val\_accuracy: 0.7304  
Epoch 2/50  
82/82 [=====] - 5s 60ms/step - loss: 0.1492 - accuracy: 0.9473 - val\_loss: 1.2062 - val\_accuracy: 0.7304  
Epoch 3/50  
82/82 [=====] - 5s 57ms/step - loss: 0.1142 - accuracy: 0.9633 - val\_loss: 0.5244 - val\_accuracy: 0.7304  
Epoch 4/50  
82/82 [=====] - 5s 62ms/step - loss: 0.1168 - accuracy: 0.9561 - val\_loss: 0.4143 - val\_accuracy: 0.7537  
Epoch 5/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0856 - accuracy: 0.9637 - val\_loss: 1.1674 - val\_accuracy: 0.7328  
Epoch 6/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0715 - accuracy: 0.9763 - val\_loss: 0.7982 - val\_accuracy: 0.7978  
Epoch 7/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0540 - accuracy: 0.9832 - val\_loss: 2.1268 - val\_accuracy: 0.7328  
Epoch 8/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0545 - accuracy: 0.9813 - val\_loss: 2.1507 - val\_accuracy: 0.7390  
Epoch 9/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0732 - accuracy: 0.9710 - val\_loss: 0.1569 - val\_accuracy: 0.9534  
Epoch 10/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0405 - accuracy: 0.9866 - val\_loss: 0.2362 - val\_accuracy: 0.9375  
Epoch 11/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0402 - accuracy: 0.9832 - val\_loss: 0.5580 - val\_accuracy: 0.8064  
Epoch 12/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0637 - accuracy: 0.9775 - val\_loss: 0.3815 - val\_accuracy: 0.8076  
Epoch 13/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0331 - accuracy: 0.9901 - val\_loss: 1.2331 - val\_accuracy: 0.7157  
Epoch 14/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0259 - accuracy: 0.9905 - val\_loss: 0.1651 - val\_accuracy: 0.9461  
Epoch 15/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0495 - accuracy: 0.9828 - val\_loss: 0.4625 - val\_accuracy: 0.7635  
Epoch 16/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0391 - accuracy: 0.9843 - val\_loss: 1.4282 - val\_accuracy: 0.7439



Epoch 17/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0257 - accuracy: 0.9905 - val\_loss: 0.7775 - val\_accuracy: 0.7549  
Epoch 18/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0473 - accuracy: 0.9832 - val\_loss: 1.0573 - val\_accuracy: 0.7525  
Epoch 19/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0449 - accuracy: 0.9843 - val\_loss: 0.1743 - val\_accuracy: 0.9363  
Epoch 20/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0449 - accuracy: 0.9855 - val\_loss: 1.2284 - val\_accuracy: 0.7819  
Epoch 21/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0172 - accuracy: 0.9927 - val\_loss: 0.1502 - val\_accuracy: 0.9620  
Epoch 22/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0053 - accuracy: 0.9992 - val\_loss: 0.3531 - val\_accuracy: 0.9277  
Epoch 23/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0100 - accuracy: 0.9958 - val\_loss: 0.4342 - val\_accuracy: 0.9179  
Epoch 24/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0087 - accuracy: 0.9966 - val\_loss: 0.2910 - val\_accuracy: 0.9301  
Epoch 25/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0102 - accuracy: 0.9962 - val\_loss: 0.2054 - val\_accuracy: 0.9596  
Epoch 26/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0051 - accuracy: 0.9985 - val\_loss: 0.2180 - val\_accuracy: 0.9547  
Epoch 27/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0362 - accuracy: 0.9893 - val\_loss: 0.1878 - val\_accuracy: 0.9412  
Epoch 28/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0166 - accuracy: 0.9927 - val\_loss: 0.1541 - val\_accuracy: 0.9583  
Epoch 29/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0210 - accuracy: 0.9912 - val\_loss: 1.3779 - val\_accuracy: 0.5527  
Epoch 30/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0209 - accuracy: 0.9931 - val\_loss: 0.4824 - val\_accuracy: 0.8186  
Epoch 31/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0211 - accuracy: 0.9935 - val\_loss: 0.2137 - val\_accuracy: 0.9154  
Epoch 32/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0043 - accuracy: 0.9985 - val\_loss: 0.1625 - val\_accuracy: 0.9608  
Epoch 33/50  
82/82 [=====] - 5s 66ms/step - loss: 0.0051 - accuracy: 0.9985 - val\_loss: 0.1959 - val\_accuracy: 0.9559  
Epoch 34/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0078 - accuracy: 0.9973 - val\_loss: 0.4505 - val\_accuracy: 0.9240  
Epoch 35/50  
82/82 [=====] - 5s 64ms/step - loss: 0.0046 - accuracy:

racy: 0.9985 - val\_loss: 0.1944 - val\_accuracy: 0.9547  
Epoch 36/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0027 - accu  
racy: 0.9996 - val\_loss: 0.6928 - val\_accuracy: 0.9179  
Epoch 37/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0119 - accu  
racy: 0.9950 - val\_loss: 0.2695 - val\_accuracy: 0.9547  
Epoch 38/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0114 - accu  
racy: 0.9966 - val\_loss: 0.1976 - val\_accuracy: 0.9571  
Epoch 39/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0086 - accu  
racy: 0.9973 - val\_loss: 0.2367 - val\_accuracy: 0.9559  
Epoch 40/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0109 - accu  
racy: 0.9954 - val\_loss: 1.6707 - val\_accuracy: 0.7475  
Epoch 41/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0322 - accu  
racy: 0.9882 - val\_loss: 0.7735 - val\_accuracy: 0.8199  
Epoch 42/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0086 - accu  
racy: 0.9977 - val\_loss: 0.4883 - val\_accuracy: 0.9265  
Epoch 43/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0013 - accu  
racy: 1.0000 - val\_loss: 0.3553 - val\_accuracy: 0.9301  
Epoch 44/50  
82/82 [=====] - 5s 60ms/step - loss: 4.3486e-04 -  
accuracy: 1.0000 - val\_loss: 0.2387 - val\_accuracy: 0.9596  
Epoch 45/50  
82/82 [=====] - 5s 58ms/step - loss: 4.0936e-04 -  
accuracy: 1.0000 - val\_loss: 0.2392 - val\_accuracy: 0.9608  
Epoch 46/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0015 - accu  
racy: 0.9992 - val\_loss: 0.9642 - val\_accuracy: 0.8591  
Epoch 47/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0310 - accu  
racy: 0.9893 - val\_loss: 0.7884 - val\_accuracy: 0.6385  
Epoch 48/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0143 - accu  
racy: 0.9947 - val\_loss: 0.3472 - val\_accuracy: 0.9020  
Epoch 49/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0097 - accu  
racy: 0.9973 - val\_loss: 1.9123 - val\_accuracy: 0.7659  
Epoch 50/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0108 - accu  
racy: 0.9973 - val\_loss: 0.7340 - val\_accuracy: 0.9179  
21/21 [=====] - 0s 10ms/step - loss: 0.8600 - accu  
racy: 0.8976  
Epoch 1/50  
82/82 [=====] - 5s 60ms/step - loss: 0.2450 - accu  
racy: 0.9049 - val\_loss: 0.6962 - val\_accuracy: 0.7304  
Epoch 2/50  
82/82 [=====] - 5s 61ms/step - loss: 0.1694 - accu  
racy: 0.9374 - val\_loss: 0.8706 - val\_accuracy: 0.7304  
Epoch 3/50  
82/82 [=====] - 5s 58ms/step - loss: 0.1260 - accu

racy: 0.9496 - val\_loss: 0.3338 - val\_accuracy: 0.8125  
Epoch 4/50  
82/82 [=====] - 5s 57ms/step - loss: 0.1118 - accu  
racy: 0.9568 - val\_loss: 0.4842 - val\_accuracy: 0.7733  
Epoch 5/50  
82/82 [=====] - 5s 60ms/step - loss: 0.1070 - accu  
racy: 0.9576 - val\_loss: 0.2219 - val\_accuracy: 0.9265  
Epoch 6/50  
82/82 [=====] - 5s 59ms/step - loss: 0.1060 - accu  
racy: 0.9591 - val\_loss: 1.9251 - val\_accuracy: 0.4203  
Epoch 7/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0823 - accu  
racy: 0.9698 - val\_loss: 2.4522 - val\_accuracy: 0.7304  
Epoch 8/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0781 - accu  
racy: 0.9698 - val\_loss: 0.1265 - val\_accuracy: 0.9571  
Epoch 9/50  
82/82 [=====] - 5s 56ms/step - loss: 0.0637 - accu  
racy: 0.9775 - val\_loss: 0.8204 - val\_accuracy: 0.7880  
Epoch 10/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0643 - accu  
racy: 0.9748 - val\_loss: 0.3145 - val\_accuracy: 0.8676  
Epoch 11/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0432 - accu  
racy: 0.9866 - val\_loss: 0.1046 - val\_accuracy: 0.9583  
Epoch 12/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0392 - accu  
racy: 0.9828 - val\_loss: 0.1481 - val\_accuracy: 0.9583  
Epoch 13/50  
82/82 [=====] - 5s 58ms/step - loss: 0.0397 - accu  
racy: 0.9851 - val\_loss: 2.5614 - val\_accuracy: 0.7304  
Epoch 14/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0304 - accu  
racy: 0.9897 - val\_loss: 3.2460 - val\_accuracy: 0.7304  
Epoch 15/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0605 - accu  
racy: 0.9782 - val\_loss: 0.7900 - val\_accuracy: 0.7806  
Epoch 16/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0483 - accu  
racy: 0.9809 - val\_loss: 0.2197 - val\_accuracy: 0.9400  
Epoch 17/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0371 - accu  
racy: 0.9874 - val\_loss: 0.4665 - val\_accuracy: 0.8272  
Epoch 18/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0239 - accu  
racy: 0.9931 - val\_loss: 0.1910 - val\_accuracy: 0.9510  
Epoch 19/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0205 - accu  
racy: 0.9943 - val\_loss: 0.1438 - val\_accuracy: 0.9596  
Epoch 20/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0118 - accu  
racy: 0.9950 - val\_loss: 0.2242 - val\_accuracy: 0.9583  
Epoch 21/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0195 - accu  
racy: 0.9908 - val\_loss: 1.1741 - val\_accuracy: 0.8395  
Epoch 22/50

82/82 [=====] - 5s 59ms/step - loss: 0.0214 - accuracy: 0.9920 - val\_loss: 0.2117 - val\_accuracy: 0.9510  
Epoch 23/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0293 - accuracy: 0.9893 - val\_loss: 1.9573 - val\_accuracy: 0.7304  
Epoch 24/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0348 - accuracy: 0.9859 - val\_loss: 0.5923 - val\_accuracy: 0.8346  
Epoch 25/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0310 - accuracy: 0.9870 - val\_loss: 0.4450 - val\_accuracy: 0.8370  
Epoch 26/50  
82/82 [=====] - 5s 57ms/step - loss: 0.0159 - accuracy: 0.9947 - val\_loss: 0.3321 - val\_accuracy: 0.9338  
Epoch 27/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0126 - accuracy: 0.9962 - val\_loss: 0.9510 - val\_accuracy: 0.6703  
Epoch 28/50  
82/82 [=====] - 5s 59ms/step - loss: 0.0087 - accuracy: 0.9977 - val\_loss: 0.2697 - val\_accuracy: 0.9301  
Epoch 29/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0025 - accuracy: 0.9992 - val\_loss: 0.1868 - val\_accuracy: 0.9632  
Epoch 30/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0011 - accuracy: 0.9996 - val\_loss: 0.2356 - val\_accuracy: 0.9534  
Epoch 31/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0067 - accuracy: 0.9981 - val\_loss: 1.6368 - val\_accuracy: 0.8272  
Epoch 32/50  
82/82 [=====] - 5s 66ms/step - loss: 0.0031 - accuracy: 0.9992 - val\_loss: 0.2068 - val\_accuracy: 0.9547  
Epoch 33/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0213 - accuracy: 0.9939 - val\_loss: 0.3568 - val\_accuracy: 0.9179  
Epoch 34/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0226 - accuracy: 0.9916 - val\_loss: 0.1645 - val\_accuracy: 0.9510  
Epoch 35/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0265 - accuracy: 0.9893 - val\_loss: 0.1898 - val\_accuracy: 0.9424  
Epoch 36/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0127 - accuracy: 0.9947 - val\_loss: 0.1916 - val\_accuracy: 0.9363  
Epoch 37/50  
82/82 [=====] - 5s 62ms/step - loss: 0.0074 - accuracy: 0.9977 - val\_loss: 0.8800 - val\_accuracy: 0.8725  
Epoch 38/50  
82/82 [=====] - 5s 60ms/step - loss: 0.0037 - accuracy: 0.9989 - val\_loss: 0.7935 - val\_accuracy: 0.8076  
Epoch 39/50  
82/82 [=====] - 5s 61ms/step - loss: 0.0012 - accuracy: 1.0000 - val\_loss: 0.2267 - val\_accuracy: 0.9547  
Epoch 40/50  
82/82 [=====] - 5s 63ms/step - loss: 0.0013 - accuracy: 0.9996 - val\_loss: 0.3618 - val\_accuracy: 0.9559

```

Epoch 41/50
82/82 [=====] - 5s 58ms/step - loss: 0.0093 - accu
racy: 0.9962 - val_loss: 1.1304 - val_accuracy: 0.8848
Epoch 42/50
82/82 [=====] - 5s 62ms/step - loss: 0.0563 - accu
racy: 0.9798 - val_loss: 2.7854 - val_accuracy: 0.7426
Epoch 43/50
82/82 [=====] - 5s 59ms/step - loss: 0.0315 - accu
racy: 0.9878 - val_loss: 0.1571 - val_accuracy: 0.9485
Epoch 44/50
82/82 [=====] - 5s 60ms/step - loss: 0.0113 - accu
racy: 0.9958 - val_loss: 0.1778 - val_accuracy: 0.9559
Epoch 45/50
82/82 [=====] - 5s 60ms/step - loss: 0.0065 - accu
racy: 0.9977 - val_loss: 0.3592 - val_accuracy: 0.8971
Epoch 46/50
82/82 [=====] - 5s 64ms/step - loss: 0.0072 - accu
racy: 0.9966 - val_loss: 0.6951 - val_accuracy: 0.8554
Epoch 47/50
82/82 [=====] - 5s 61ms/step - loss: 0.0210 - accu
racy: 0.9912 - val_loss: 0.8966 - val_accuracy: 0.8100
Epoch 48/50
82/82 [=====] - 5s 60ms/step - loss: 0.0292 - accu
racy: 0.9908 - val_loss: 0.2381 - val_accuracy: 0.9387
Epoch 49/50
82/82 [=====] - 5s 59ms/step - loss: 0.0187 - accu
racy: 0.9927 - val_loss: 1.8851 - val_accuracy: 0.6679

```

```
In [134]: save_result('CNN #6', results_train[1], results_test[1], cvs[0], cvs[1], cv
s[2], cvs[3], cvs[4])
```

Out[134]:

	model_name	Train Accuracy	Test Accuracy	CV1	CV2	CV3	CV4	CV5	CV_Std	CV_avg
0	CNN #3	1.000	0.953	0.965	0.953	0.960	0.953	0.966	0.007	0.959
0	CNN #2	1.000	0.947	0.953	0.956	0.960	0.953	0.963	0.005	0.957
0	CNN #1	0.953	0.933	0.921	0.940	0.931	0.916	0.945	0.012	0.931
0	CNN #4	1.000	0.950	0.776	0.963	0.954	0.960	0.966	0.083	0.924
0	CNN #6	1.000	0.955	0.962	0.962	0.953	0.898	0.743	0.094	0.903
0	Initial Model	0.730	0.730	0.925	0.740	0.728	0.709	0.743	0.088	0.769

## Prediction for Confusion Matrix

```
In [135]: predictions = model6.predict(x = test_images, steps = 10, verbose=0)
```

```
In [136]: pred_check = np.round(predictions)
```

```
In [137]: pred_check = pred_check[:]  
pred_check = pred_check.flatten()  
pred_check
```

```
Out[137]: array([1., 1., 1., ..., 0., 0., 0.], dtype=float32)
```

```
In [138]: test_labels = test_labels[:,0]  
test_check
```

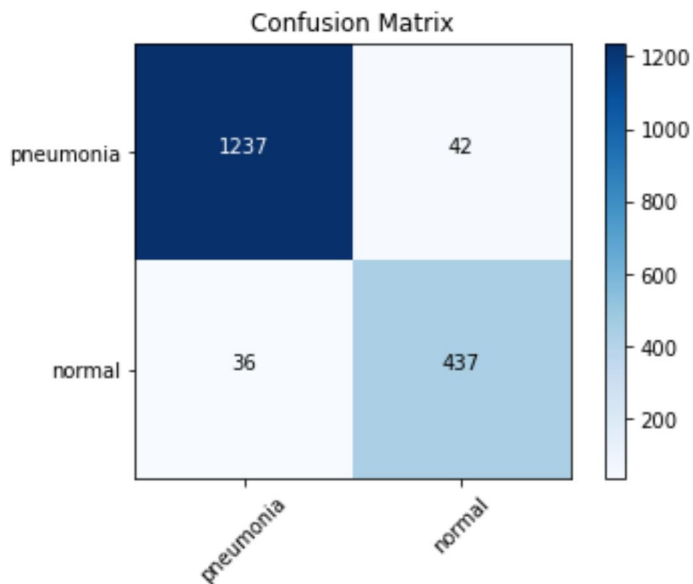
```
Out[138]: array([1., 1., 1., ..., 0., 0., 0.], dtype=float32)
```

```
In [139]: cm = confusion_matrix(y_true=test_check, y_pred=pred_check)
```

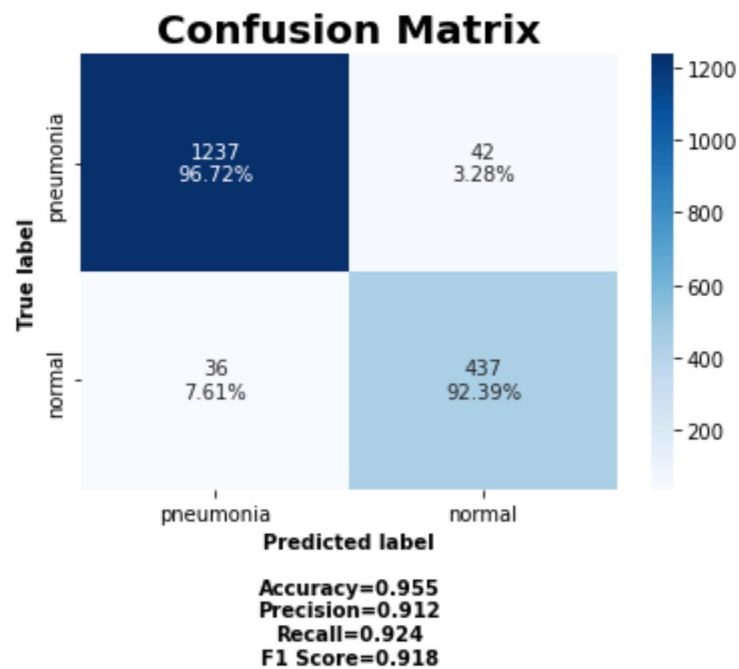
```
In [140]: cm_plot_labels = ['pneumonia', 'normal']  
plot_confusion_matrix(cm=cm, classes=cm_plot_labels, title='Confusion Matrix')
```

Confusion matrix, without normalization

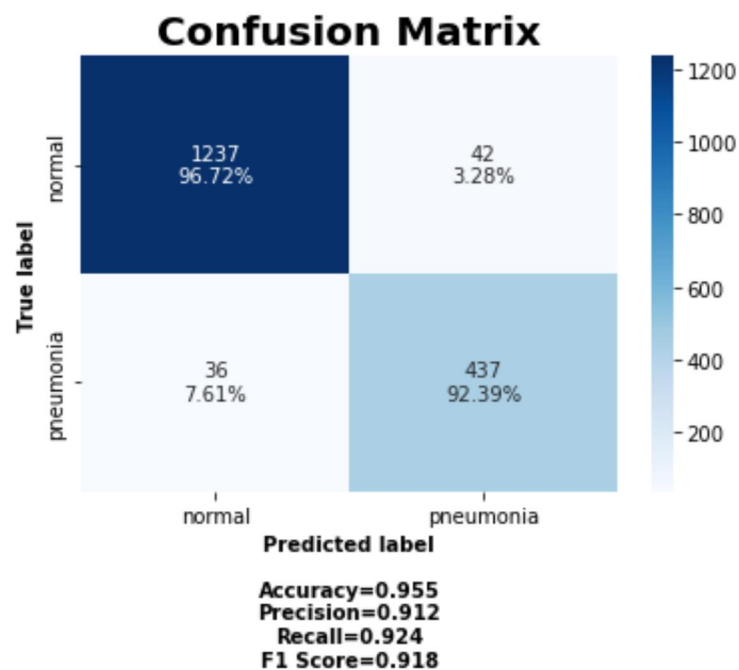
```
[[1237  42]  
 [ 36 437]]
```



```
In [141]: cm_plot_labels = ['pneumonia', 'normal']
make_confusion_matrix(cm, categories = cm_plot_labels, title='Confusion Matrix')
```



```
In [142]: cm_plot_labels = ['normal', 'pneumonia']
make_confusion_matrix(cm, categories=cm_plot_labels, title='Confusion Matrix')
```



## Expaining The Final Model With LIME

```
In [143]: import lime
          from lime import lime_image
```

```
In [144]: explainer = lime_image.LimeImageExplainer()
```

**Here, I am checking the labels and predictions of various images, then viewing the decision-making weights using LIME Explanations.**

An explanation is a local linear approximation of the models behavior. While the model may be complex globally, it is simple(r) to approximate it around the vicinity of a particular instance ([github.com/marcotcr/lime](https://github.com/marcotcr/lime))

```
In [146]: from skimage.segmentation import mark_boundaries
```

```
In [212]: def check_label(train_images_num):
          img1 = train_images[train_images_num]
          img = train_labels[train_images_num][0]
          if img == 0:
              return 'normal'
          else:
              return 'pneumonia'
```

```
In [216]: check_label(0)
```

```
Out[216]: 'pneumonia'
```

```
In [228]: def check_prediction(train_images_num):
          img = train_images[train_images_num].reshape(1, 64, 64, 3)
          pred = model3.predict(img)
          if pred[0][0] > 0.5:
              return 'pneumonia'
          else:
              return 'normal'
```

```
In [267]: def plot_image_preds(train_images_num):
          img = train_images[train_images_num].reshape(1, 64, 64, 3)
          pred = model3.predict(img)
          f, ax = plt.subplots(figsize=(10, 8))
          plt.imshow(img[0])
          plt.title('Prediction: ' + check_prediction(train_images_num) + '\n' +
                  'Label: ' + check_label(train_images_num), fontsize=20)
          plt.show()
```

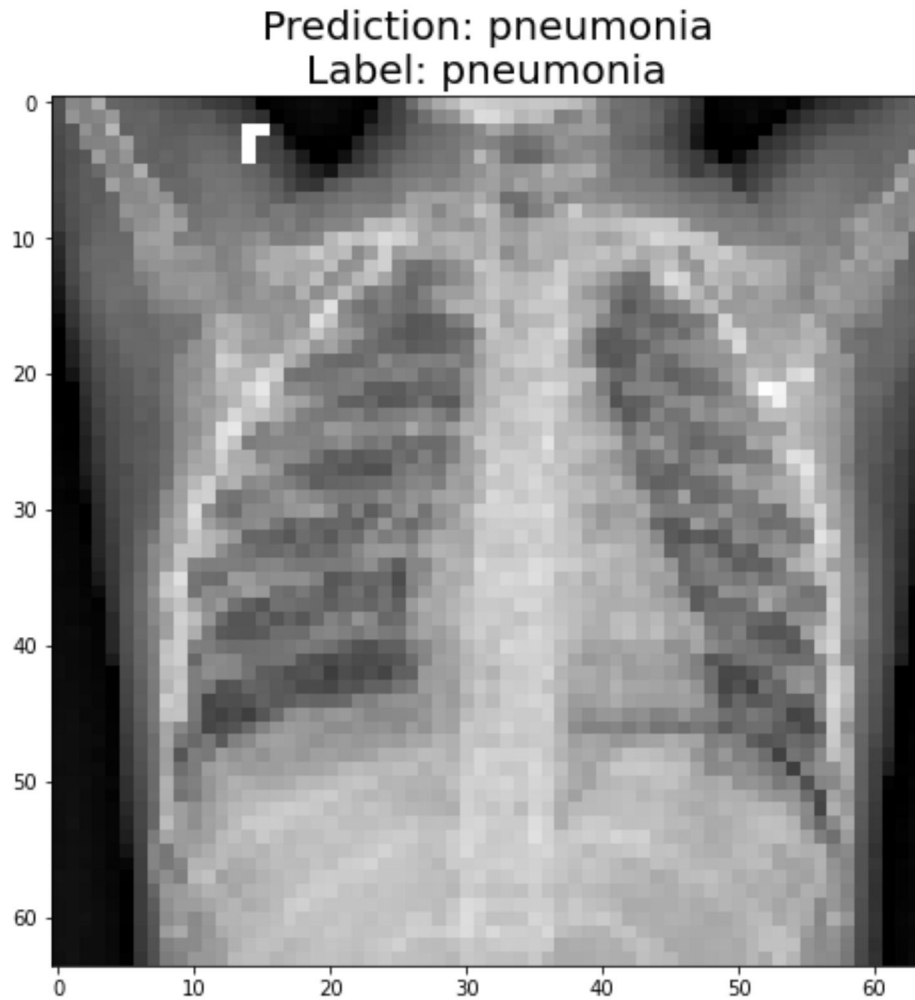
```
In [309]: def plot_explanation(exp):
          temp, mask = exp.get_image_and_mask(exp.top_labels[0], positive_only=True,
          hide_rest=False)
          f, ax = plt.subplots(figsize=(8, 8))
          plt.title('Explanation for class: ' + check_label(0), fontsize=20)
          plt.imshow(mark_boundaries(temp / 2 + 0.5, mask))
```



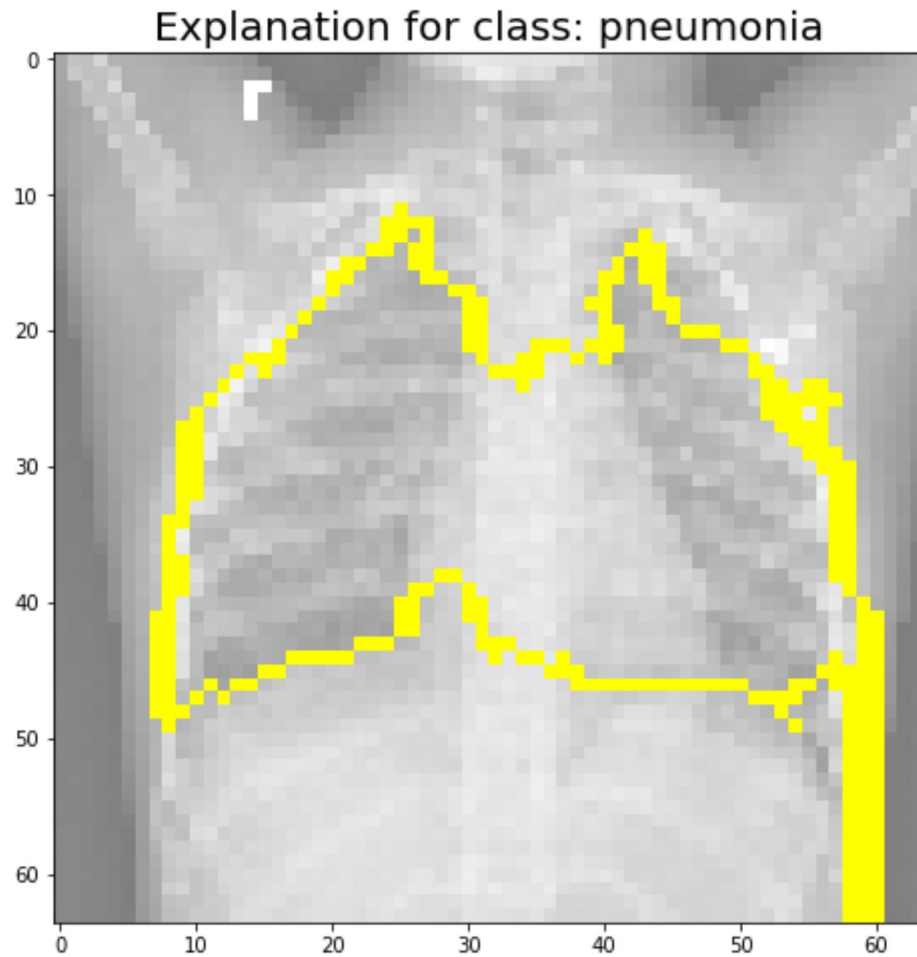
```
In [350]: # Hide color is the color for a superpixel turned OFF. Alternatively, if it
           # is NONE, the superpixel will be replaced by the average of its pixels
           expl anati on1 = expl ai ner. expl ai n_i nstance(trai n_i mages[0]. astype("doubl e"),
           model 3. predi ct, top_l abel s=2, hi de_col or=0, num_sampl es=50000)
```

100%|██████████| 50000/50000 [04:04<00:00, 204.67it/s]

```
In [351]: plot_i mage_preds(0)
```

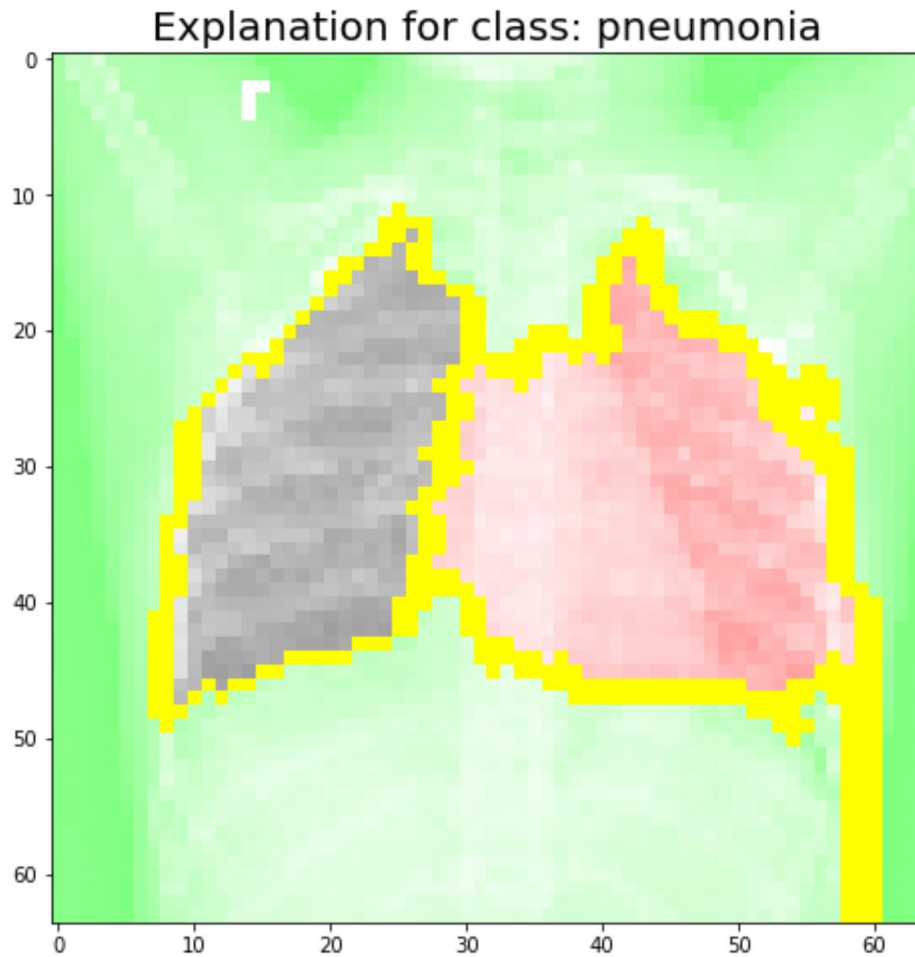


In [352]: `plot_explanation(explanation1)`



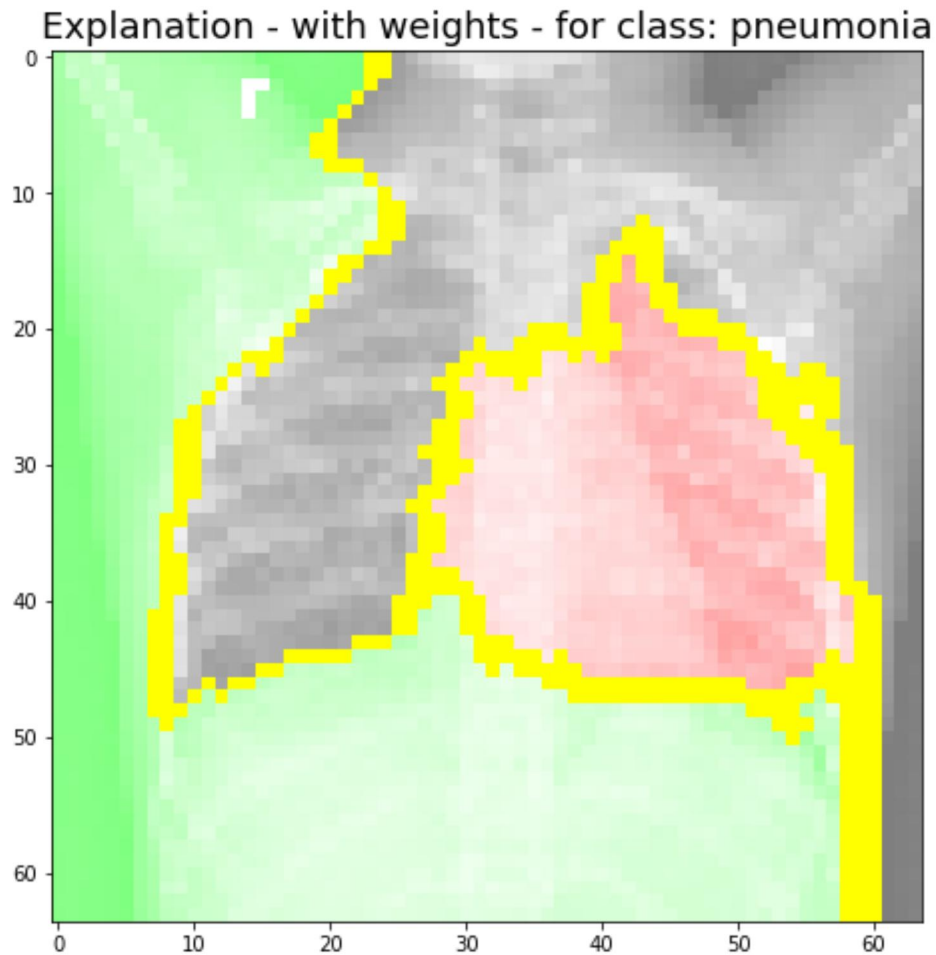
```
In [311]: def plot_pos_neg_explanation(exp):  
    temp, mask = exp.get_image_and_mask(exp.top_labels[0], positive_only=False, hide_rest=False)  
    f, ax = plt.subplots(figsize=(8, 8))  
    plt.title('Explanation for class: ' + check_label(0), fontsize=20)  
    plt.imshow(mark_boundaries(temp / 2 + 0.5, mask))
```

```
In [353]: plot_pos_neg_explanation(explanation1)
```



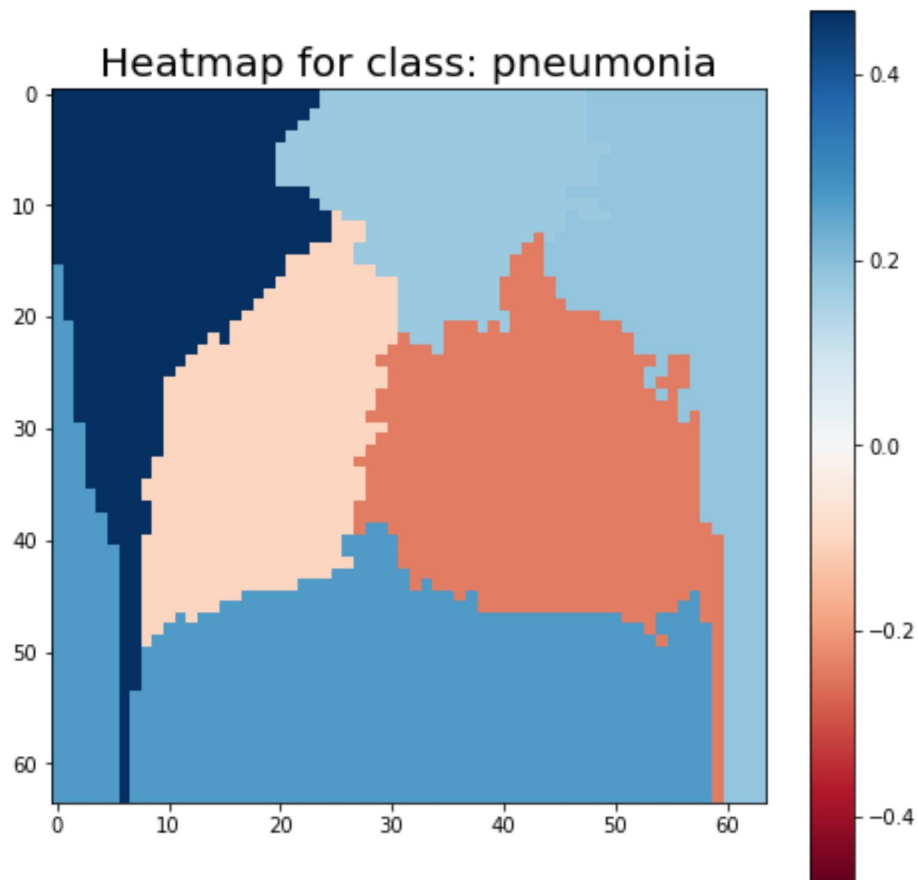
```
In [315]: def plot_with_weights(exp, mw): # mw is the minimum weight
    temp, mask = exp.get_image_and_mask(exp.top_labels[0], positive_only=False,
    hide_rest=False, min_weight = mw)
    f, ax = plt.subplots(figsize=(8, 8))
    plt.title('Explanation - with weights - for class: ' + check_label(0),
    fontsize=18)
    plt.imshow(mark_boundaries(temp / 2 + 0.5, mask))
```

```
In [354]: plot_with_weights(explanation1, 0.2)
```



```
In [322]: def plot_explanation_heatmap(exp):  
    ind = exp.top_labels[0]  
    #Map each explanation weight to the corresponding superpixel  
    dict_heatmap = dict(exp.local_exp[ind])  
    heatmap = np.vectorize(dict_heatmap.get)(exp.segments)  
    f, ax = plt.subplots(figsize=(8, 8))  
    #Plot. The visualization makes more sense if a symmetrical colorbar is used.  
    plt.imshow(heatmap, cmap = 'RdBu', vmin = -heatmap.max(), vmax = heatmap.max())  
    plt.title('Heatmap for class: ' + check_label(0), fontsize=20)  
    plt.colorbar()
```

```
In [355]: plot_explanation_heatmap(explanation1)
```

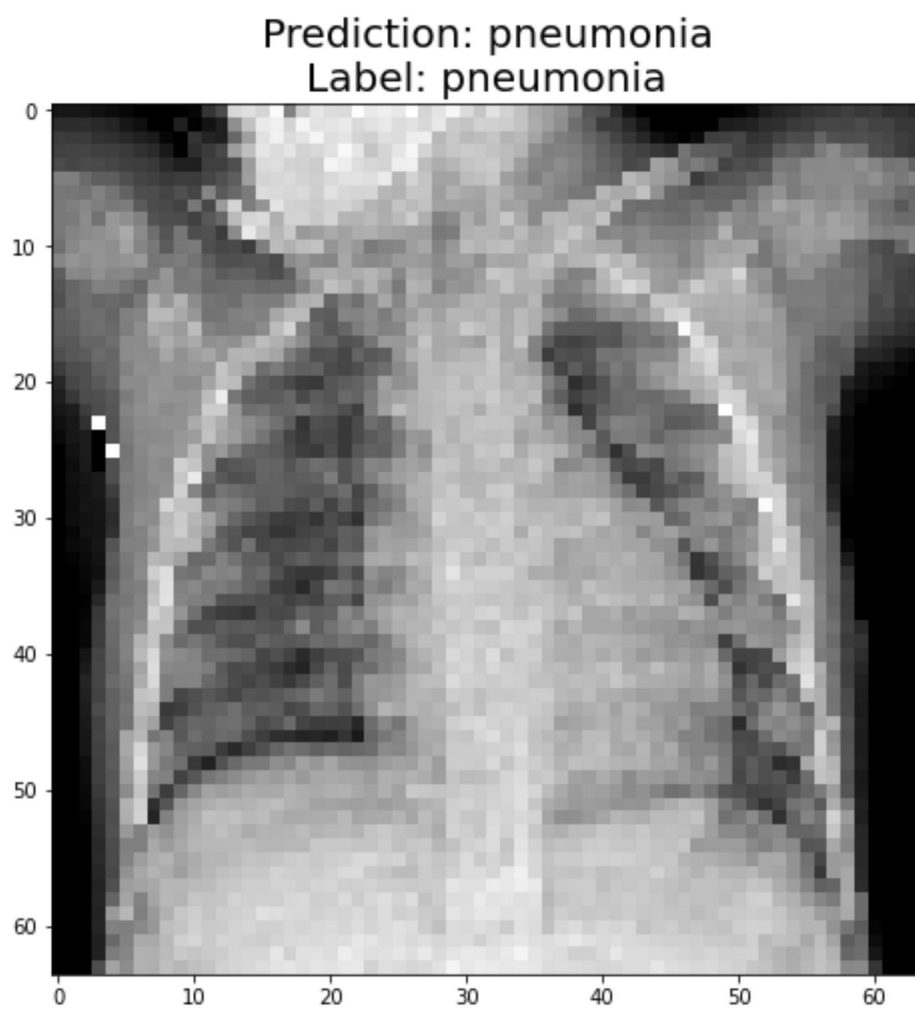


## Image 2

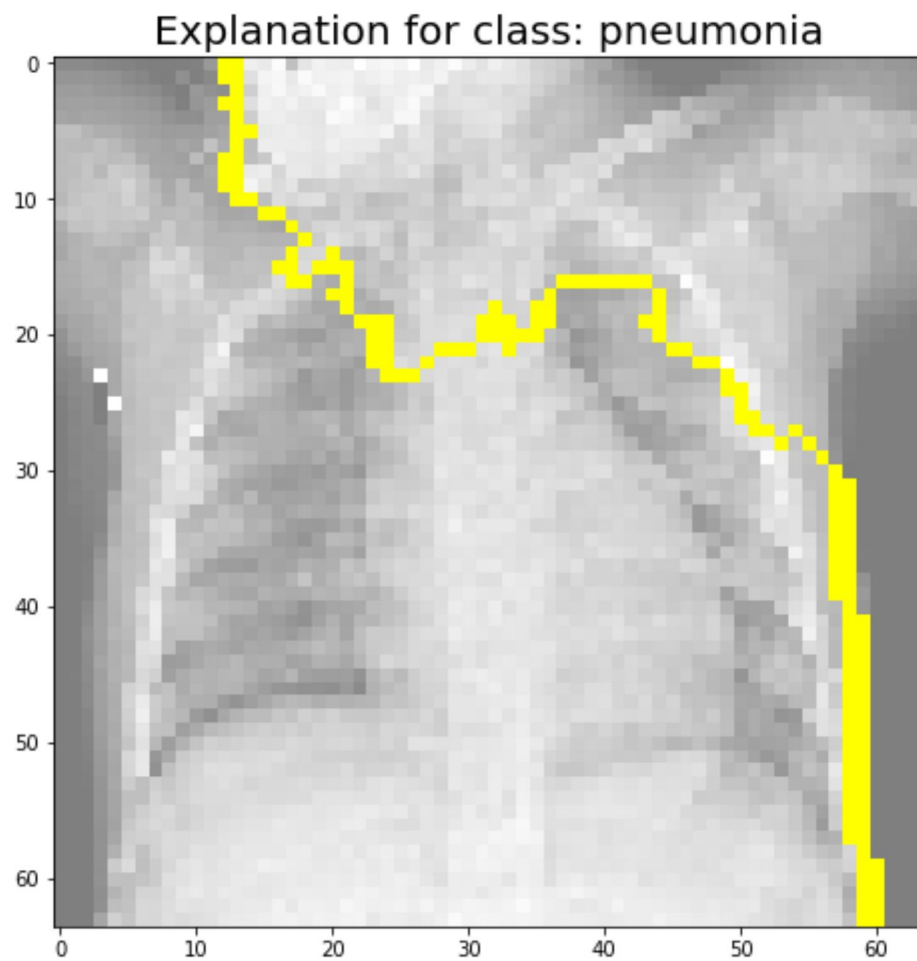
```
In [356]: # Hide color is the color for a superpixel turned OFF. Alternatively, if it
           # is NONE, the superpixel will be replaced by the average of its pixels
           explanation2 = explainer.explain_instance(train_images[12].astype("double"),
           model3.predict, top_labels = 2, hide_color=0, num_samples=100000)
```

100%|██████████| 100000/100000 [09:08<00:00, 182.15it/s]

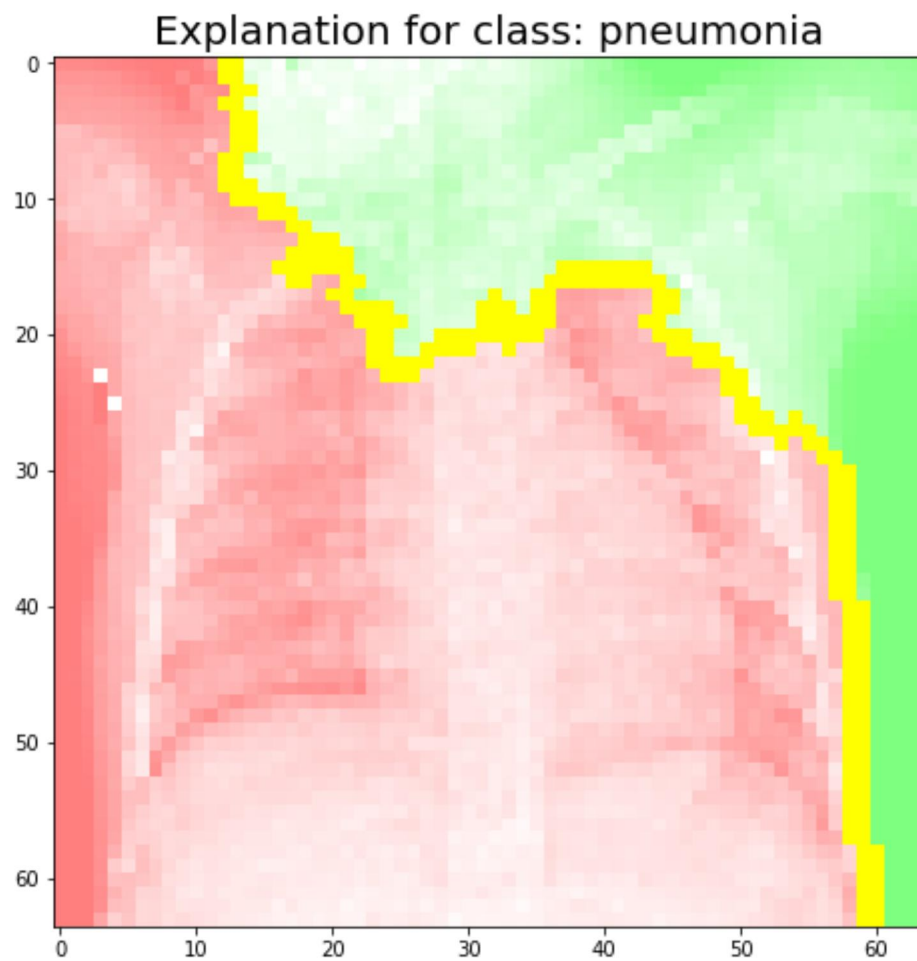
In [357]: `plot_image_preds(12)`



In [358]: `plot_explanation(explanation2)`

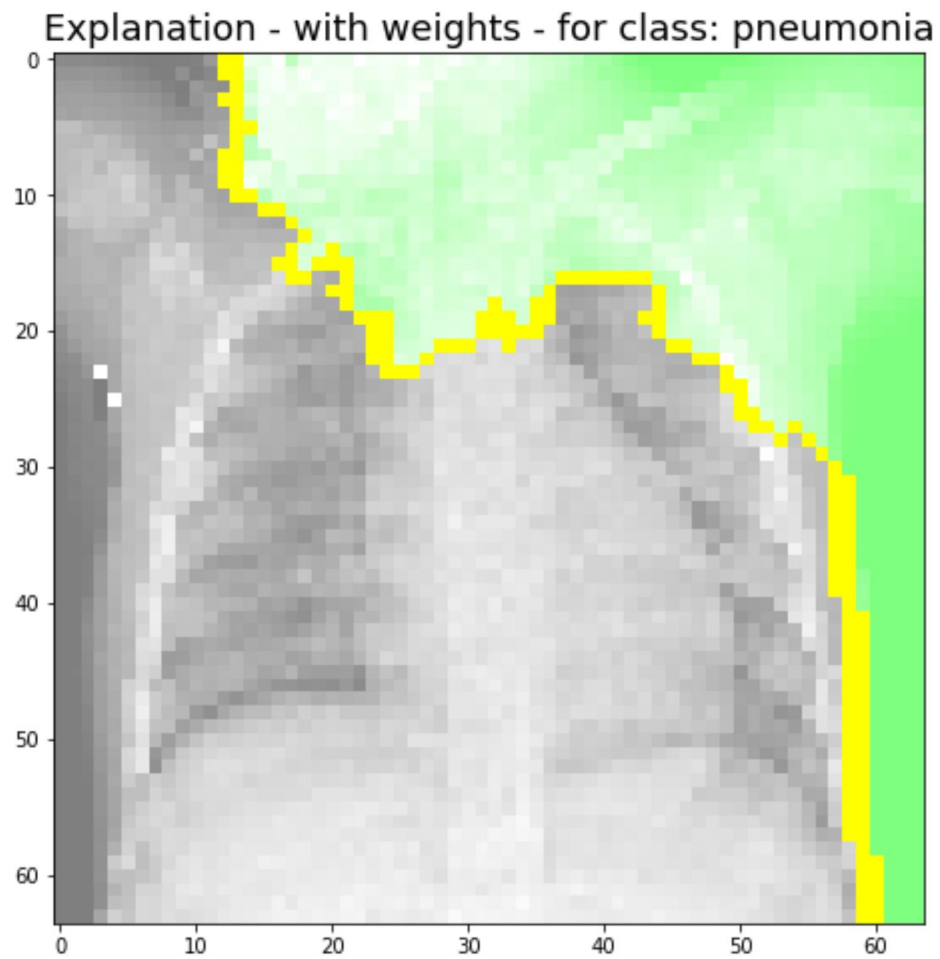


```
In [361]: plot_pos_neg_explanation(explanation2)
```

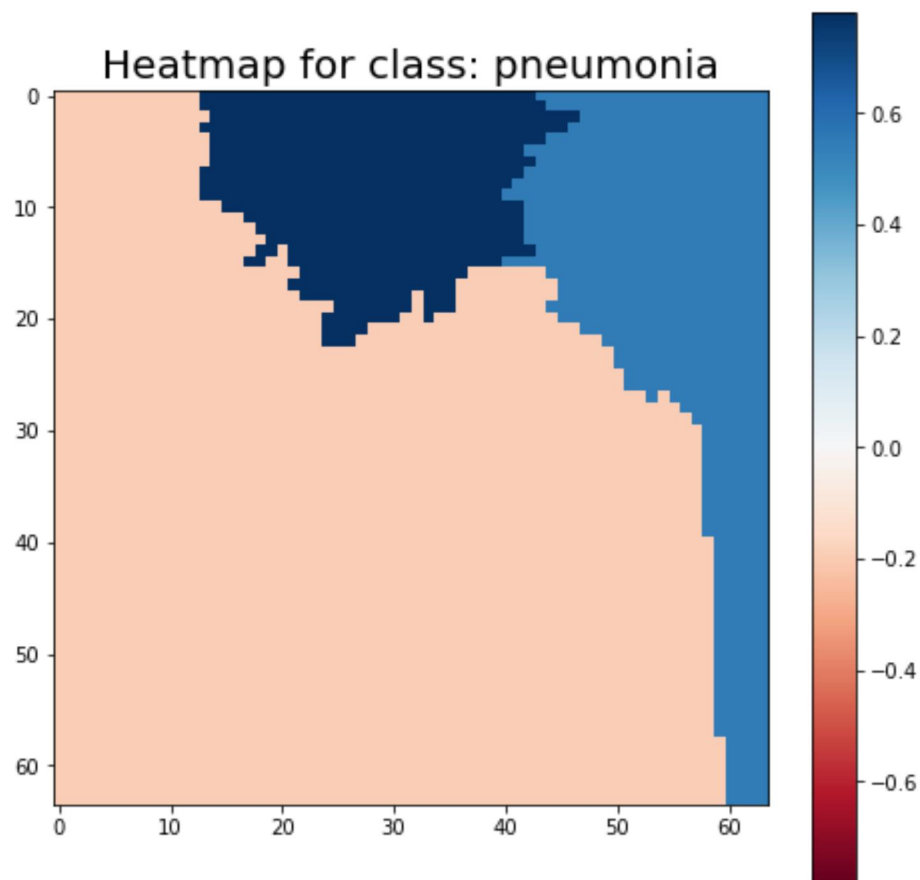




```
In [360]: plot_with_weights(explanation2, 0.2)
```



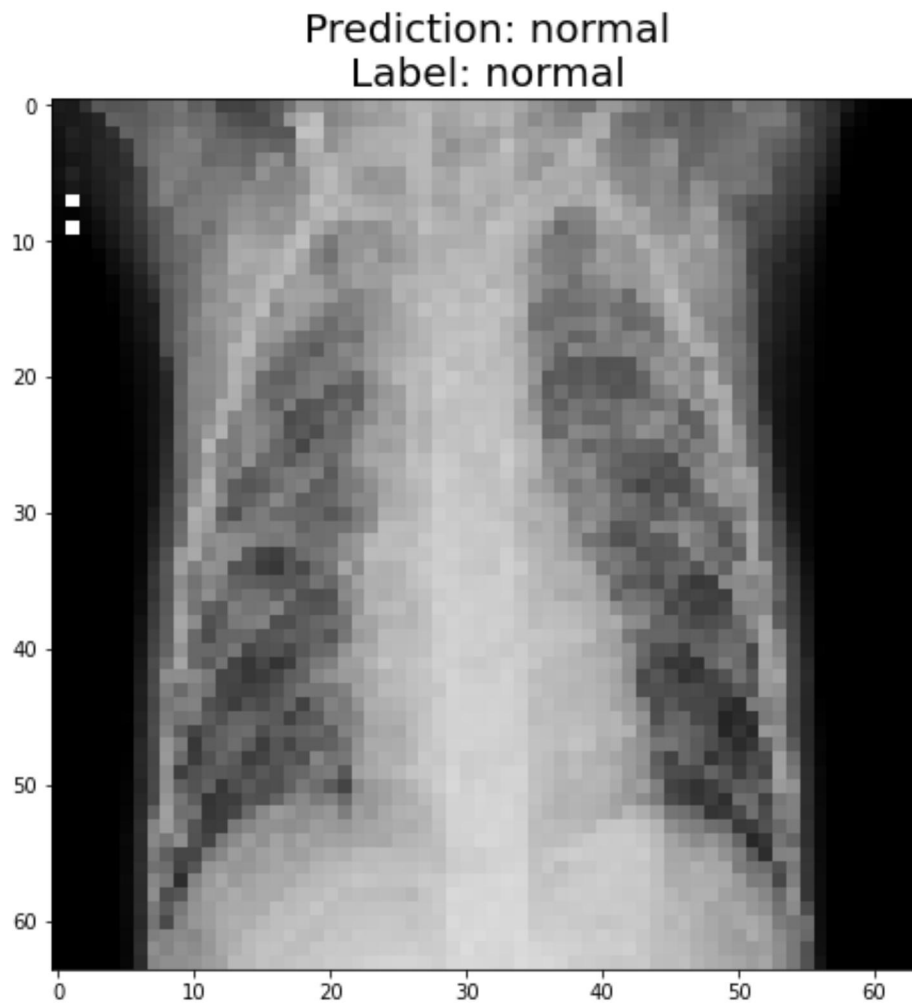
```
In [362]: plot_explanation_heatmap(explanation2)
```



### Image 3: A Positive Image

The first one I find

```
In [343]: plot_image_preds(18)
```

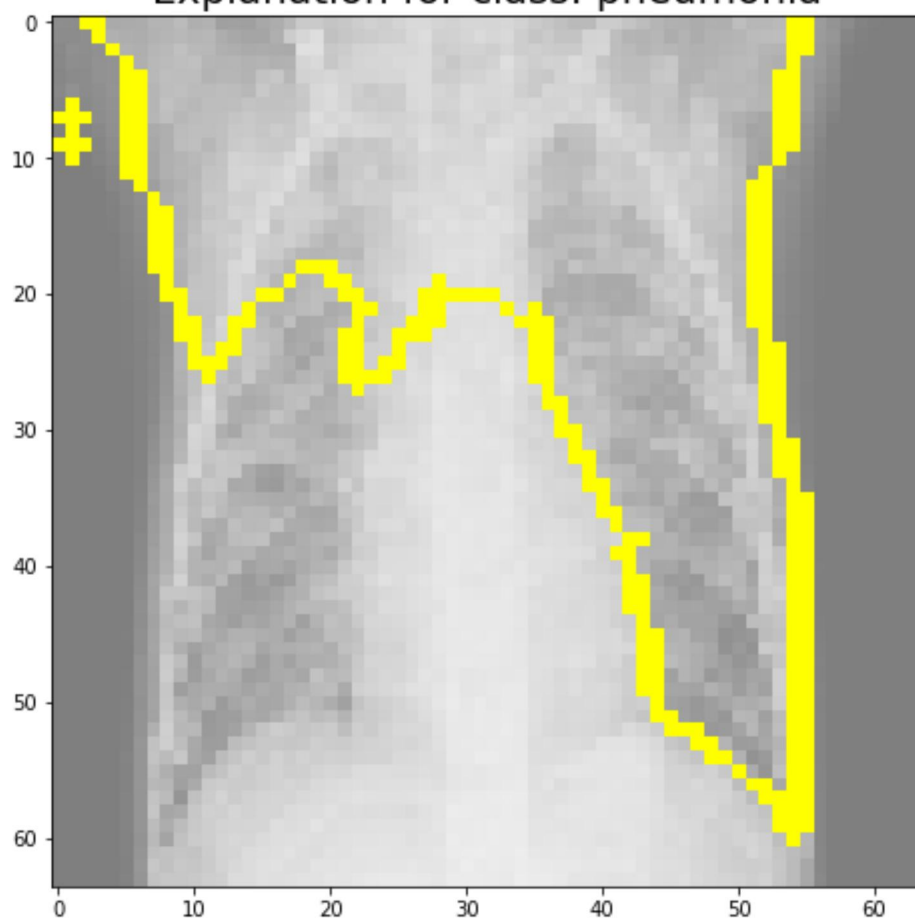


```
In [344]: explanation3 = explainer.explain_instance(train_images[18].astype("double"), model3.predict, top_labels = 2, hide_color=0, num_samples=10000)
```

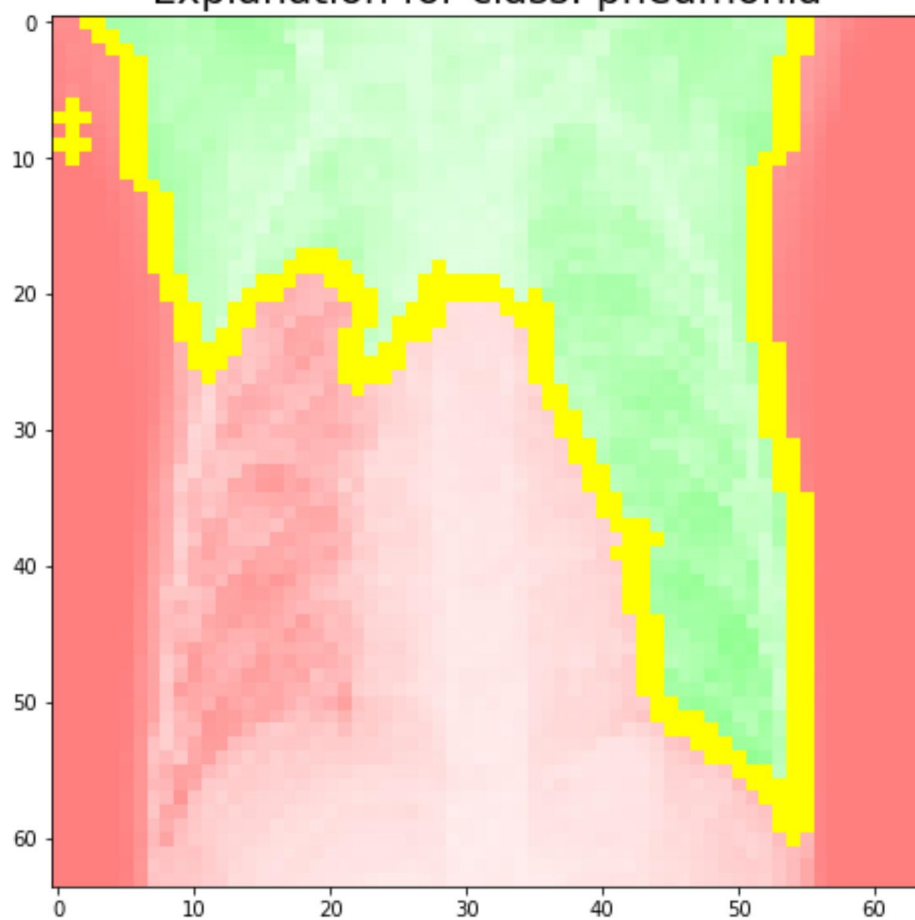
100%|██████████| 10000/10000 [00: 45<00: 00, 217.88it/s]

```
In [345]: plot_explanation(explanation3)
plot_pos_neg_explanation(explanation3)
plot_with_weights(explanation3, 0.2)
plot_explanation_heatmap(explanation3)
```

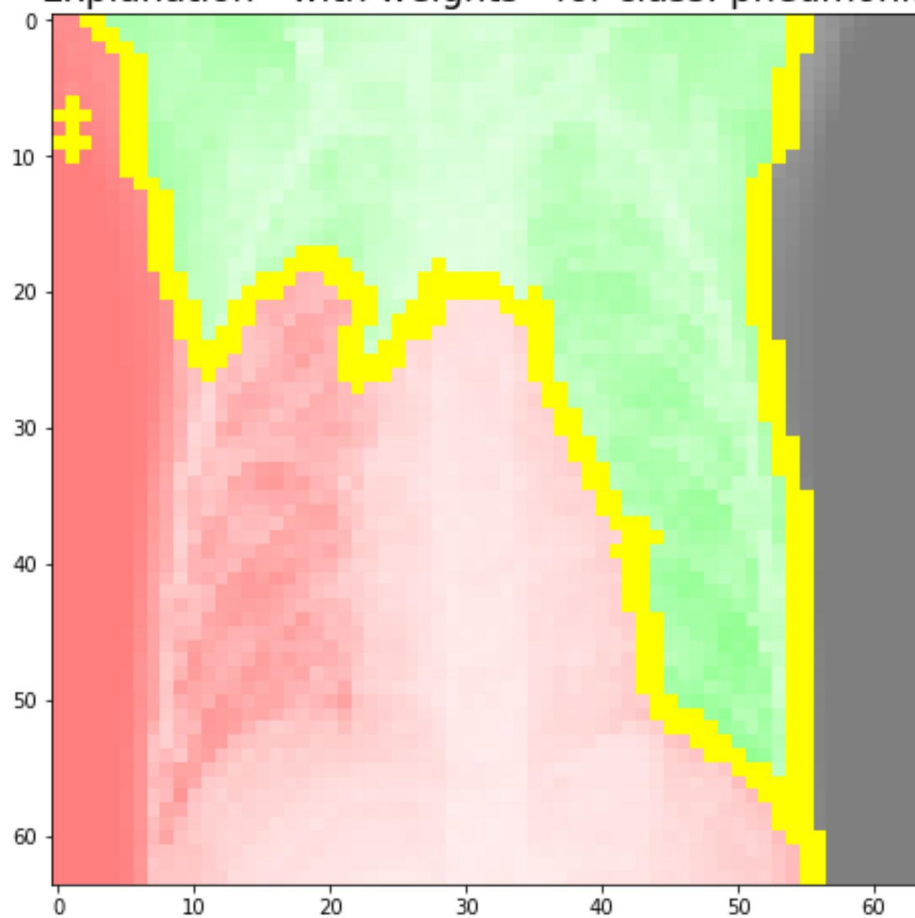
Explanation for class: pneumonia



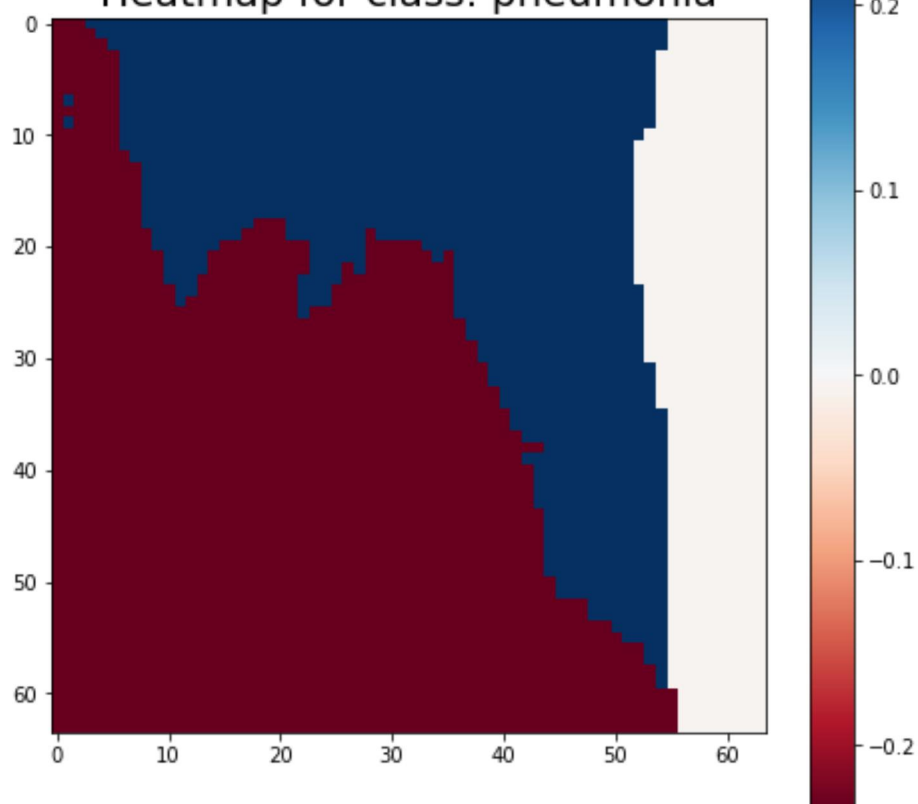
Explanation for class: pneumonia



Explanation - with weights - for class: pneumonia



Heatmap for class: pneumonia

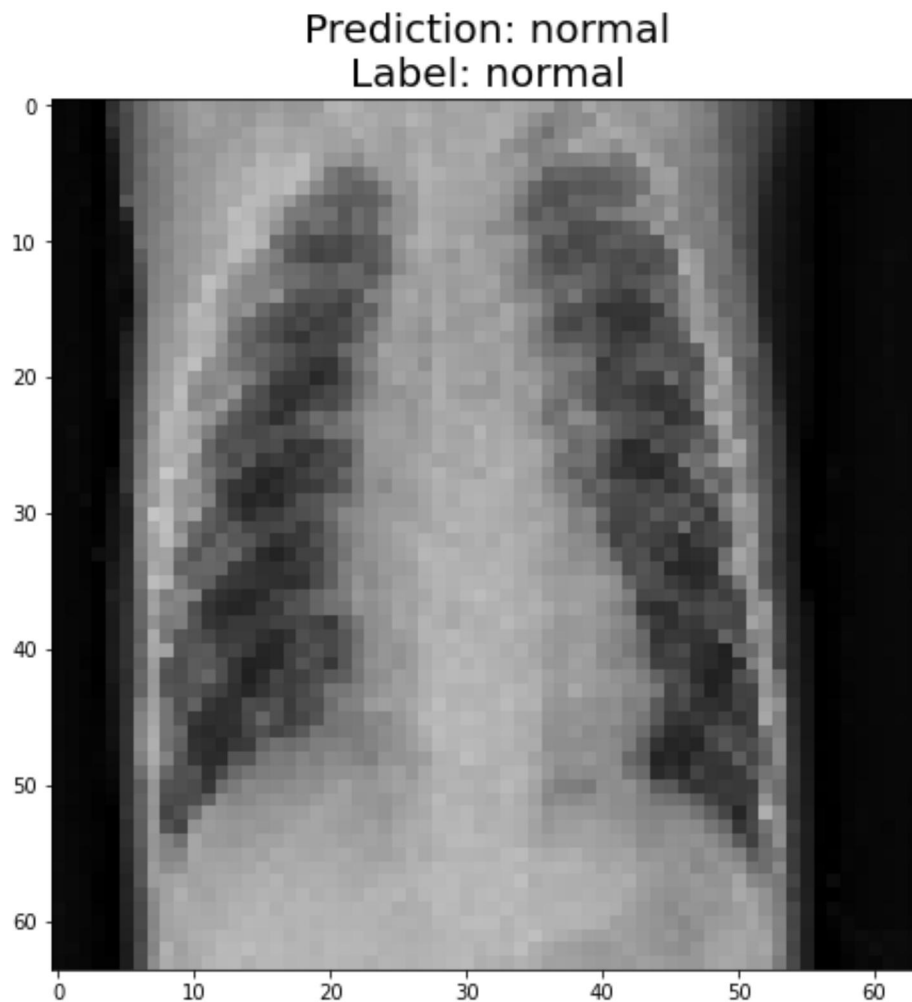


## Image 4

```
In [363]: explanation4 = explainer.explain_instance(train_images[130].astype("double"), model3.predict, top_labels = 2, hide_color=0, num_samples=20000)
```

```
100%|██████████| 20000/20000 [01:41<00:00, 197.55it/s]
```

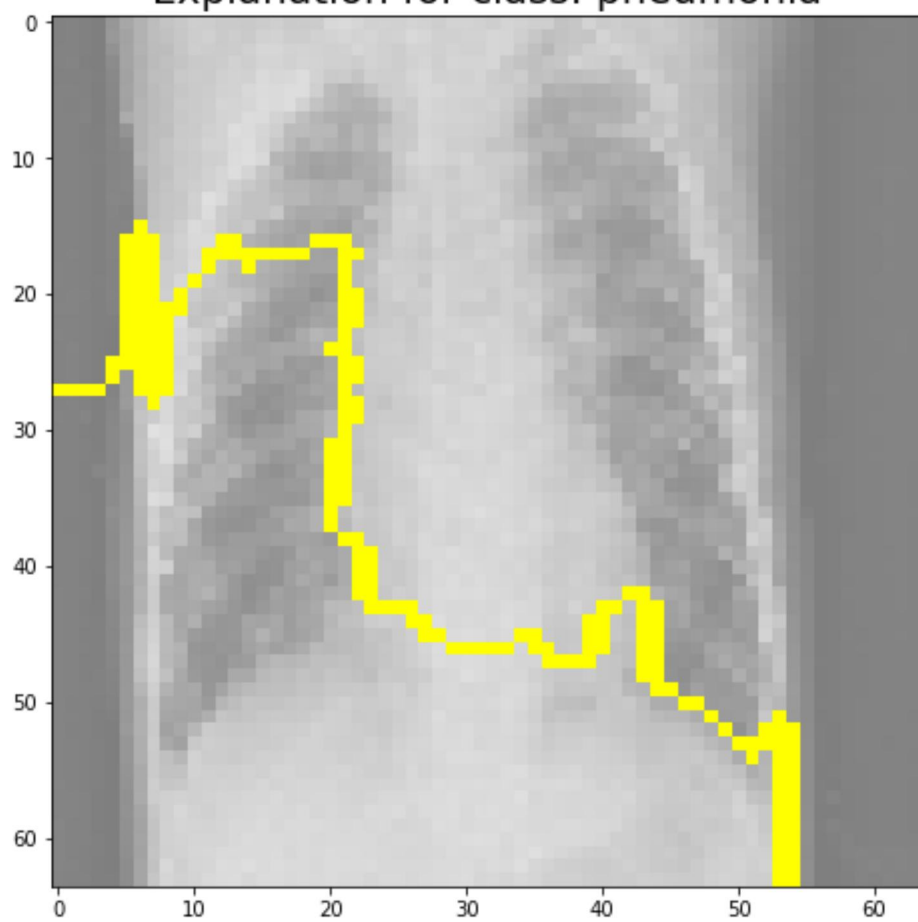
```
In [364]: plot_image_preds(130)
```



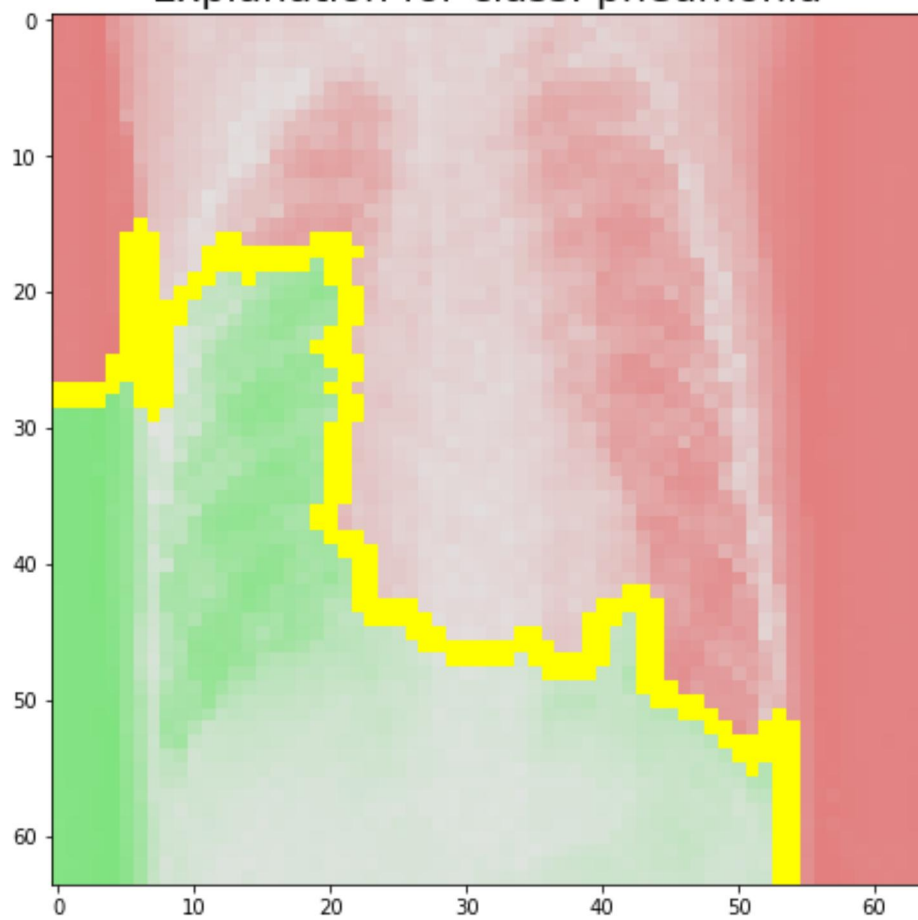


```
In [365]: plot_explanation(explanation4)
plot_pos_neg_explanation(explanation4)
plot_with_weights(explanation4, 0.2)
plot_explanation_heatmap(explanation4)
```

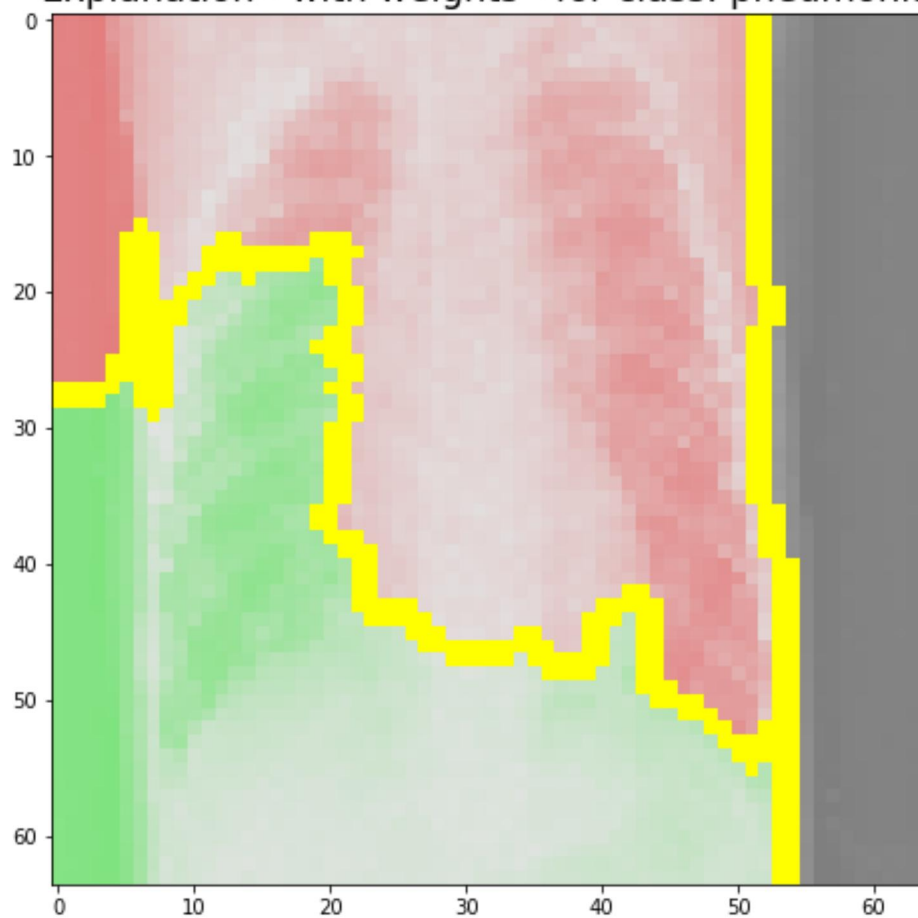
Explanation for class: pneumonia



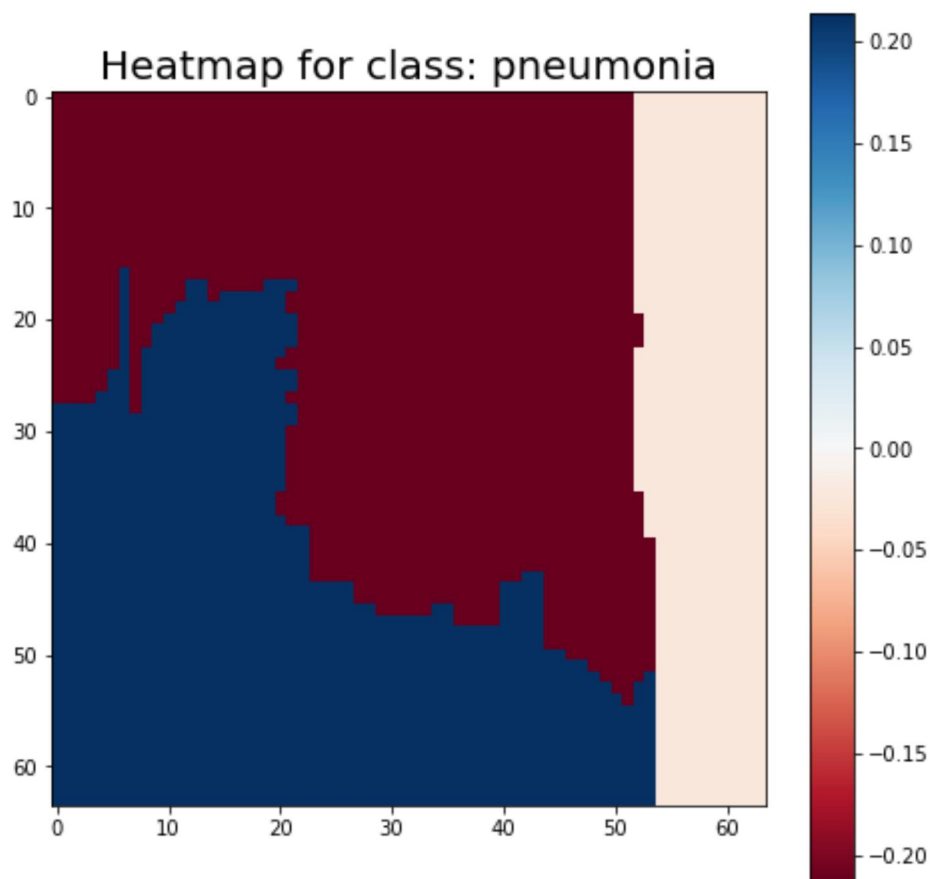
Explanation for class: pneumonia



Explanation - with weights - for class: pneumonia



Heatmap for class: pneumonia



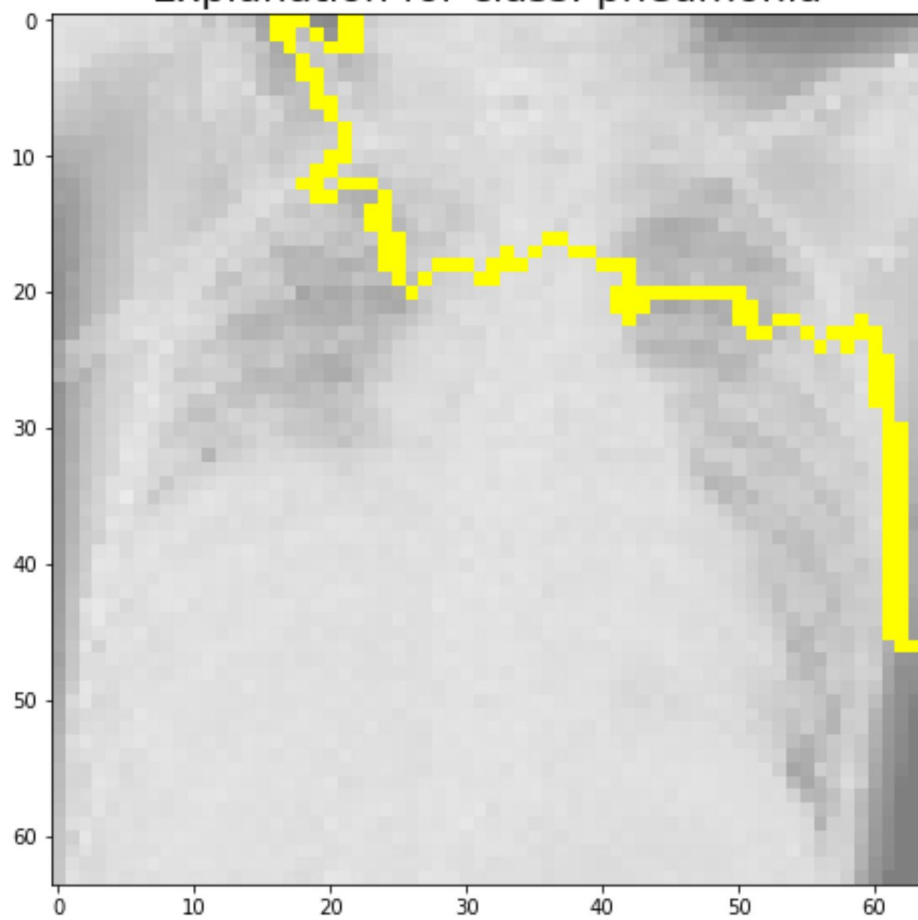
## Image 5

```
In [366]: explanation5 = explainer.explain_instance(train_images[232].astype("double"), model3.predict, top_labels = 2, hide_color=0, num_samples=20000)
```

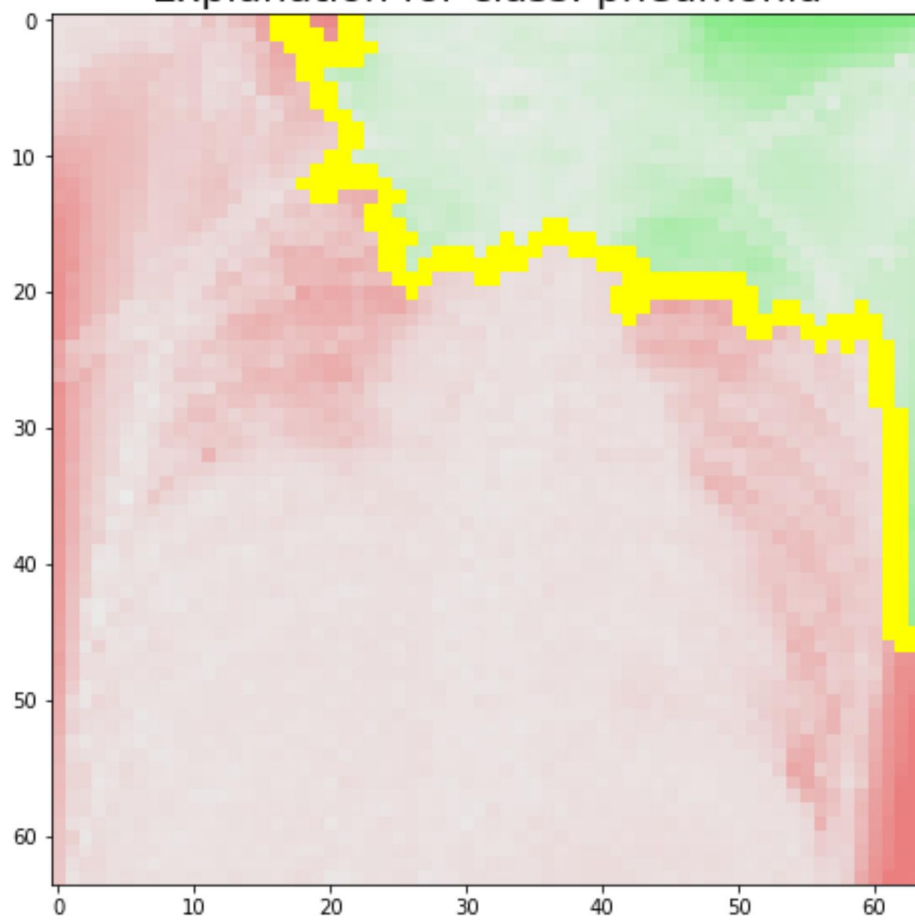
100%|██████████| 20000/20000 [02:06<00:00, 158.14it/s]

```
In [367]: plot_explanation(explanation5)
plot_pos_neg_explanation(explanation5)
plot_with_weights(explanation5, 0.2)
plot_explanation_heatmap(explanation5)
```

Explanation for class: pneumonia

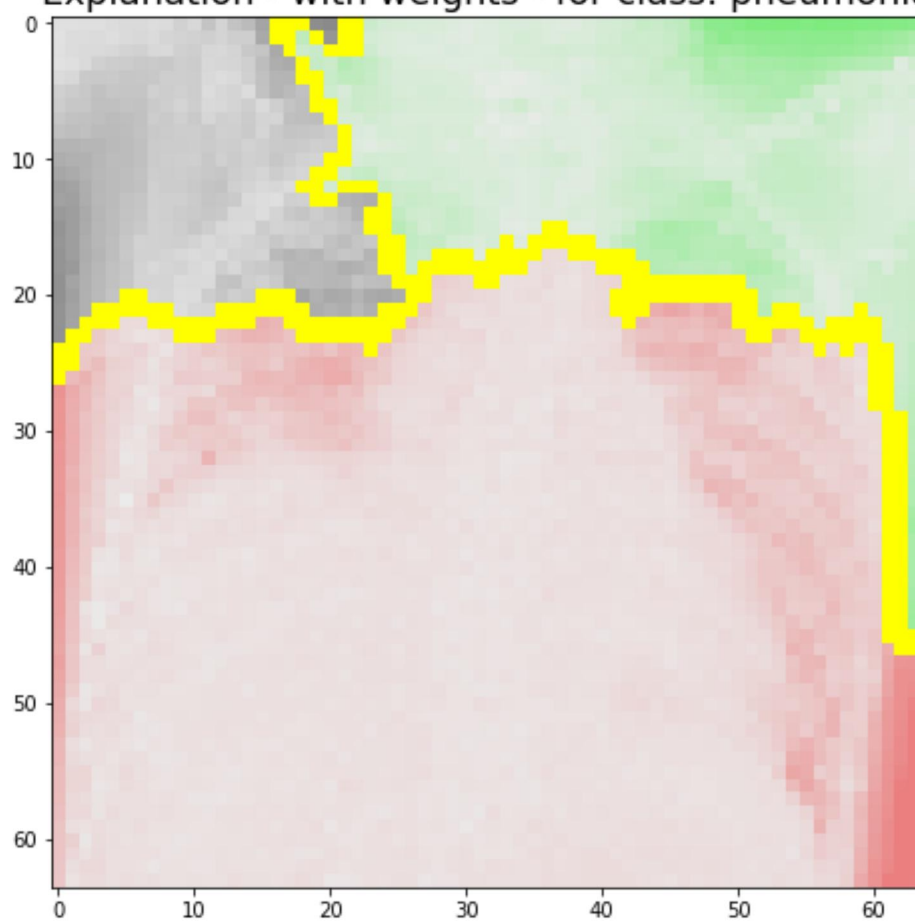


Explanation for class: pneumonia

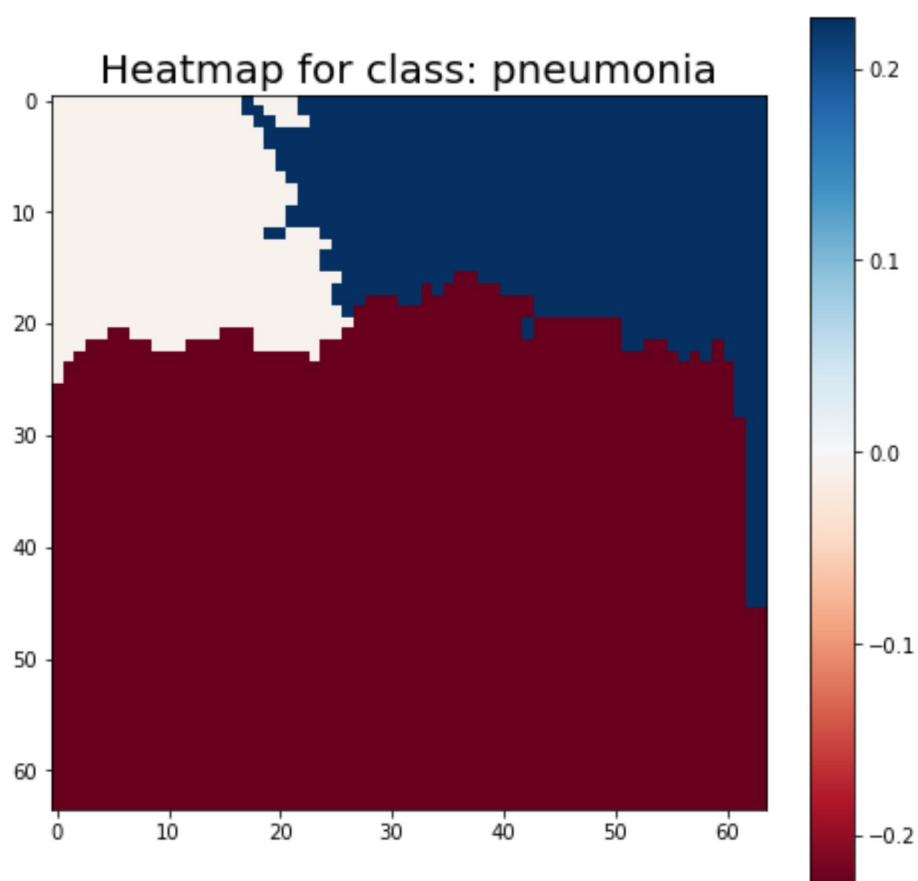




Explanation - with weights - for class: pneumonia



Heatmap for class: pneumonia



## Conclusion

I was unable to improve performance past CNN #4, making CNN #4 the final model for this project.

```
In [368]: # Model 4 Summary  
model 3.summary()
```

Model: "sequential\_13"

Layer (type)	Output Shape	Param #
=====	=====	=====
conv2d_42 (Conv2D)	(None, 62, 62, 32)	896
max_pooling2d_42 (MaxPooling)	(None, 31, 31, 32)	0
conv2d_43 (Conv2D)	(None, 28, 28, 32)	16416
batch_normalization (BatchNo	(None, 28, 28, 32)	128
max_pooling2d_43 (MaxPooling)	(None, 14, 14, 32)	0
conv2d_44 (Conv2D)	(None, 12, 12, 64)	18496
max_pooling2d_44 (MaxPooling)	(None, 6, 6, 64)	0
conv2d_45 (Conv2D)	(None, 4, 4, 128)	73856
batch_normalization_1 (Batch	(None, 4, 4, 128)	512
max_pooling2d_45 (MaxPooling)	(None, 2, 2, 128)	0
flatten_12 (Flatten)	(None, 512)	0
dense_48 (Dense)	(None, 64)	32832
dropout (Dropout)	(None, 64)	0
dense_49 (Dense)	(None, 1)	65
=====	=====	=====
Total params: 143,201		
Trainable params: 142,881		
Non-trainable params: 320		

## Final Results

The final result included 1,236 true positives, 437 true negatives, 36 false negatives, and 42 false positives.

The total accuracy was 95.5 percent.

Recall is the number of true positives divided by the total number of elements that actually belong to the positive class -i.e., true positives plus false negatives.

- Recall equaled .93.
- Precision equaled .912.
- The F1 Score equaled .918.

In product terms, this means that we could expect the model to correctly pick if an individual has pneumonia based on their x-ray 95.5 percent of the time.

If I could further this project, I would try other neural network models to see if there is a possibly better techniques for the modeling, such as LIME (locally interpretable model-agnostic explanations).

I would also attempt further data augmentation. The data augmentation I attempted did not improve the performance of the model, although that portion of the model was cut out for brevity, along with numerous other versions of the CNNs.

Thank you.