Detection of Covid Positive Cases using Image Processing

[Data Source]

Loading Required Libraries

```
import warnings
warnings.simplefilter(action='ignore', category=FutureWarning)

# Data Reading

import os
from glob import glob
from PIL import Image

# Data Processing

import numpy as np
import pandas as pd
import cv2
import random
import albumentations as A

# Data Analysis

import plotly.express as px
import matplotlib.pyplot as plt
import seaborn as sns

# Data Modeling & Model Evaluation

from sklearn.model_selection import train_test_split
from keras.preprocessing import image
from tensorflow.keras import layers, models
import tensorflow as tf
os.environ['TF_CPP_MIN_LOG_LEVEL'] = '3'
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay, classification_report, recall_score, accuracy_score, p

# Grad-CAM

import keras
import matplotlib.cm as cm
```

Reading The Data

```
levels = ['Normal', 'COVID']
path = "../input/covid19-radiography-database/COVID-19_Radiography_Dataset"
data_dir = os.path.join(path)

data = []
for id, level in enumerate(levels):
    for file in os.listdir(os.path.join(data_dir, level)):
        data.append(['{}/{}'.format(level, file), level])

data = pd.DataFrame(data, columns = ['image_file', 'corona_result'])

data['path'] = path + '/' + data['image_file']
data['corona_result'] = data['corona_result'].map({'Normal': 'Negative', 'COVID': 'Positive'})
samples = 13808

data.head()
```

	image_file	corona_result	path
0	Normal/Normal-859.png	Negative	../input/covid19-radiography-database/COVID-19...
1	Normal/Normal-158.png	Negative	../input/covid19-radiography-database/COVID-19...
2	Normal/Normal-10121.png	Negative	../input/covid19-radiography-database/COVID-19...
3	Normal/Normal-1811.png	Negative	../input/covid19-radiography-database/COVID-19...
4	Normal/Normal-97.png	Negative	../input/covid19-radiography-database/COVID-19...

```
print('Number of Duplicated Samples: %d'%(data.duplicated().sum()))
print('Number of Total Samples: %d'%(data.isnull().value_counts()))
```

```
Number of Duplicated Samples: 0
Number of Total Samples: 13808
```

Exploratory Data Analysis

1. Count Plot

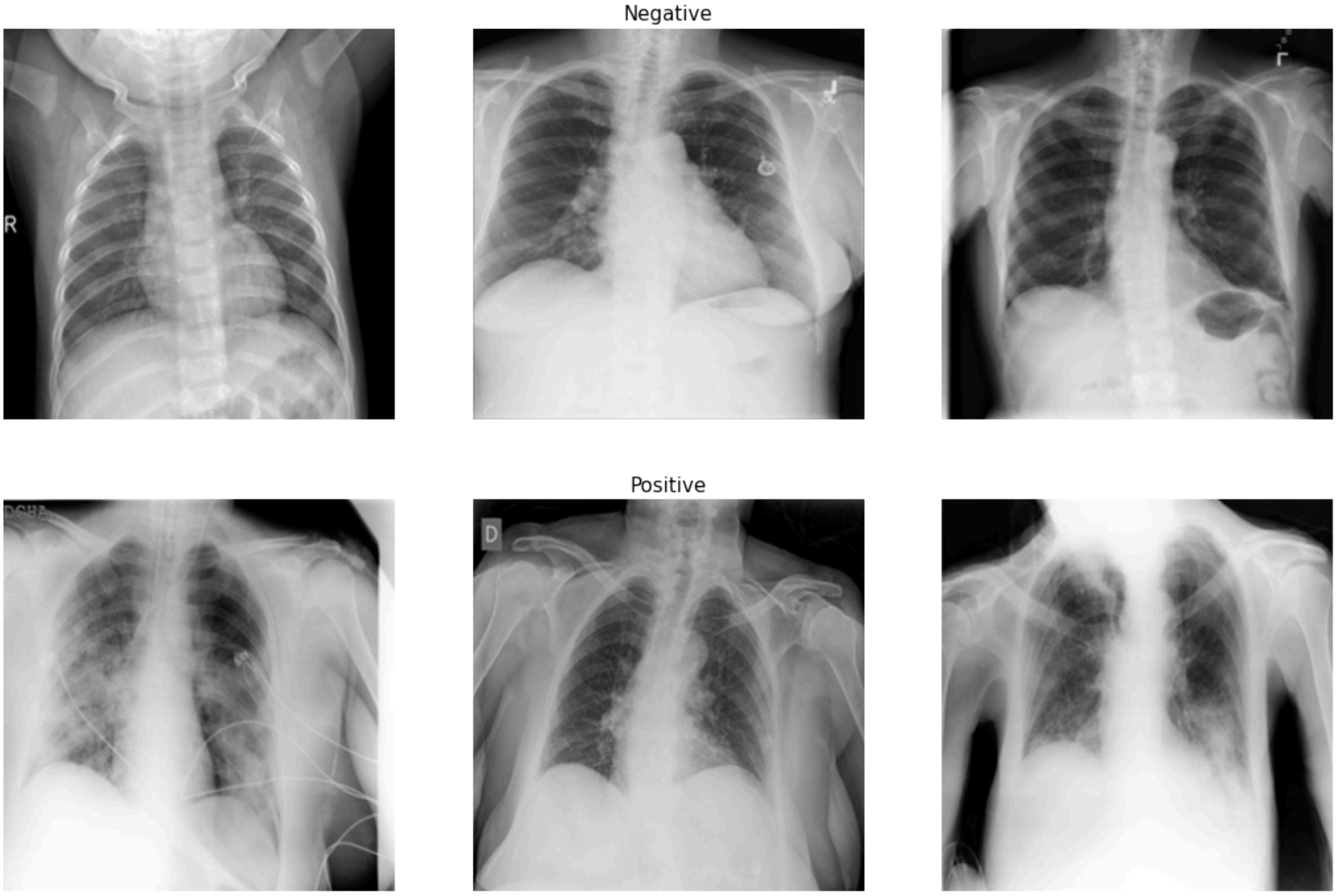
```
df = pd.DataFrame()
df['corona_result'] = ['Positive', 'Negative']
df['Count'] = [len(data[data['corona_result'] == 'Positive']), len(data[data['corona_result'] == 'Negative'])]
df = df.sort_values(by = ['Count'], ascending = False)

fig = px.bar(df, x = 'corona_result', y = 'Count',
             color = "corona_result", text_auto='', width = 600,
             color_discrete_sequence = ["orange", "purple"],
             template = 'plotly_dark')

fig.update_xaxes(showgrid = False)
fig.update_yaxes(showgrid = False)
fig.update_traces(textfont_size = 12, textangle = 0, textposition = "outside", cliponaxis = False)

fig.show()
```

2. Image Samples

```
data['image'] = data['path'].map(lambda x: np.asarray(Image.open(x).resize((75,75))))

data.head()
```

	image_file	corona_result	path	image
0	Normal/Normal-859.png	Negative	../input/covid19-radiography-database/COVID-19...	[[5, 5, 6, 6, 5, 6, 6, 6, 6, 6, 5, 6, 5, 5,...
1	Normal/Normal-158.png	Negative	../input/covid19-radiography-database/COVID-19...	[[64, 85, 96, 97, 115, 138, 130, 133, 141, 112...
2	Normal/Normal-10121.png	Negative	../input/covid19-radiography-database/COVID-19...	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...
3	Normal/Normal-1811.png	Negative	../input/covid19-radiography-database/COVID-19...	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 5, 9, 15, 2...
4	Normal/Normal-97.png	Negative	../input/covid19-radiography-database/COVID-19...	[[96, 111, 136, 152, 170, 163, 160, 176, 175, ...

```
n_samples = 3

fig, m_axs = plt.subplots(2, n_samples, figsize = (6*n_samples, 3*4))

for n_axs, (type_name, type_rows) in zip(m_axs, data.sort_values(['corona_result']).groupby('corona_result')):
    n_axs[1].set_title(type_name, fontsize = 15)
    for c_ax, (_, c_row) in zip(n_axs, type_rows.sample(n_samples, random_state = 1234).iterrows()):
        picture = c_row['path']
        image = cv2.imread(picture)
        c_ax.imshow(image)
        c_ax.axis('off')
```



3. Random Image Analysis

```
plt.figure()
image = cv2.imread("../input/covid19-radiography-database/COVID-19_Radiography_Dataset/COVID/COVID-1002.png")
plt.imshow(image)
plt.axis('off')
plt.show()
```

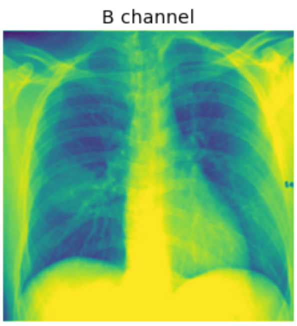
```
print('Image Shape: {}'.format(image.shape))
print('Image Height: {}'.format(image.shape[0]))
print('Image Width: {}'.format(image.shape[1]))
print('Image Dimension: {}'.format(image.ndim))
print('Image Size: {}kb'.format(image.size//1024))
print('Image Data Type: {}'.format(image.dtype))
print('Maximum RGB value of the image: {}'.format(image.max()))
print('Minimum RGB value of the image: {}'.format(image.min()))
```

```
Image Shape: (299, 299, 3)
Image Height: 299
Image Width: 299
Image Dimension: 3
Image Size: 261kb
Image Data Type: uint8
Maximum RGB value of the image: 255
Minimum RGB value of the image: 5
```

> We observe that the image has 3 channels, hence it in in RGB scale even if these are X-ray images.

4. B-Channel

```
plt.title('B channel', fontsize = 14)
plt.imshow(image[ : , : , 0])
plt.axis('off');
plt.show()
```



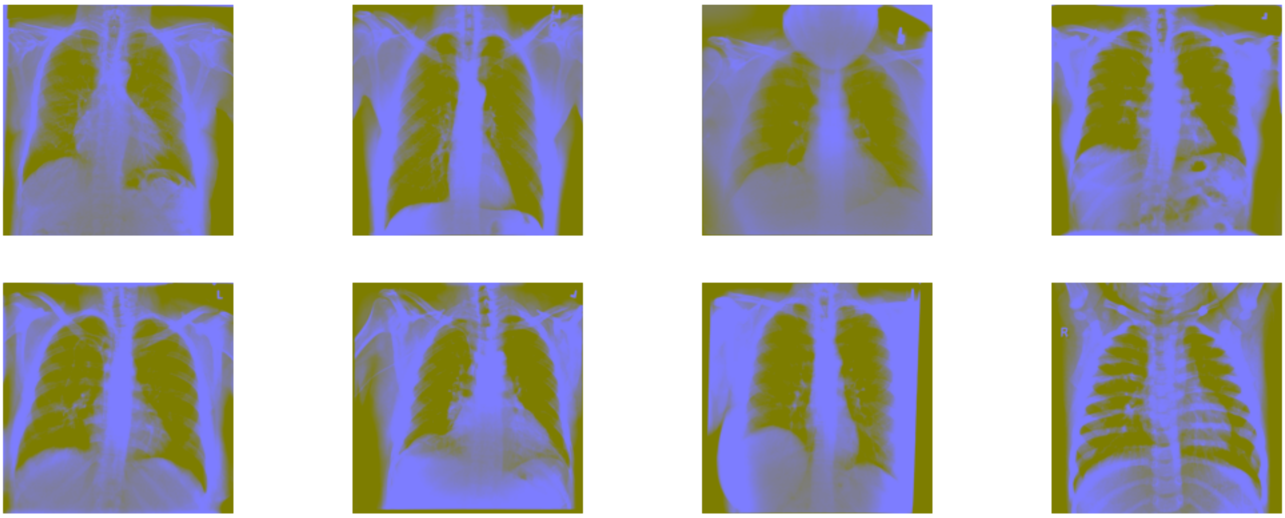
5. Ben Graham's Method

> First, we convert the images to greyscale and then apply Gaussian blur to them.

```
all_covid = []
all_normal = []

all_normal.extend(glob(os.path.join(path, "Normal/*.png")))
all_covid.extend(glob(os.path.join(path, "COVID/*.png")))

random.shuffle(all_normal)
random.shuffle(all_covid)

images = all_normal[:50] + all_covid[:50]


fig = plt.figure(figsize = (18, 7))
fig.suptitle("Ben Grahamns Method of Analysis", fontsize = 15)
columns = 4; rows = 2
```

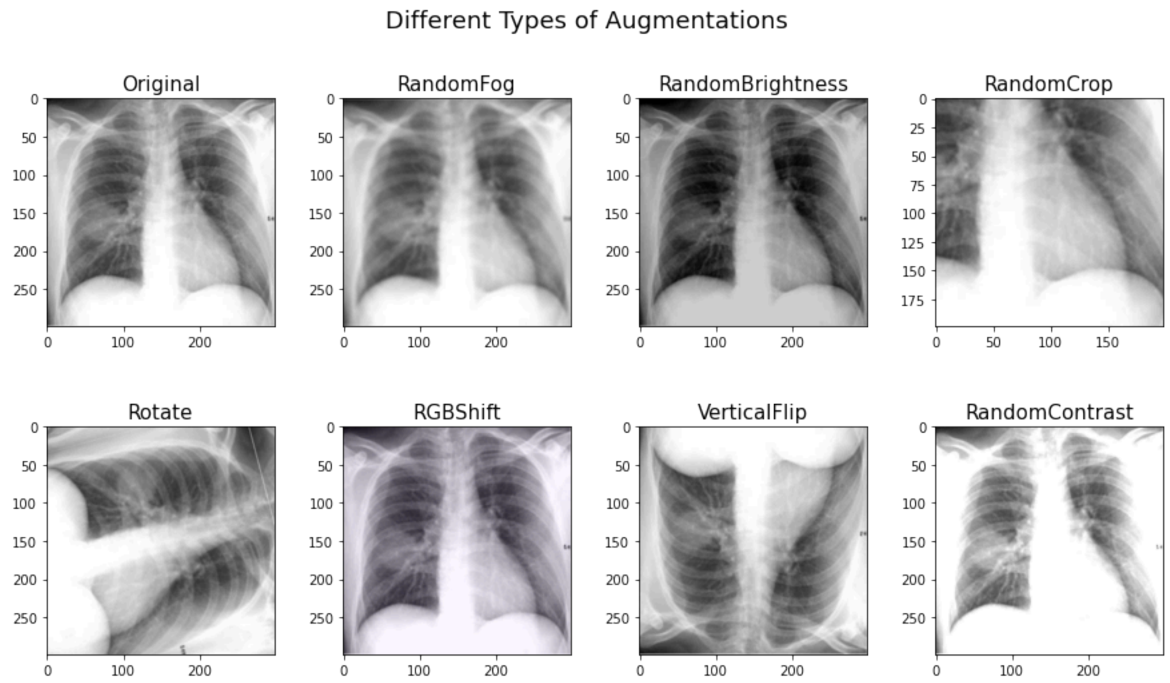
```
for i in range(1, columns*rows +1):
    img = cv2.imread(images[i])
    img = cv2.resize(img, (512, 512))
    img = cv2.cvtColor(img, cv2.COLOR_BGR2HSV)
    img = cv2.addWeighted (img, 4, cv2.GaussianBlur(img, (0,0), 512/10), -4, 128)
    fig.add_subplot(rows, columns, i)
    plt.imshow(img)
    plt.axis(False)
```

Ben Grahamns Method of Analysis



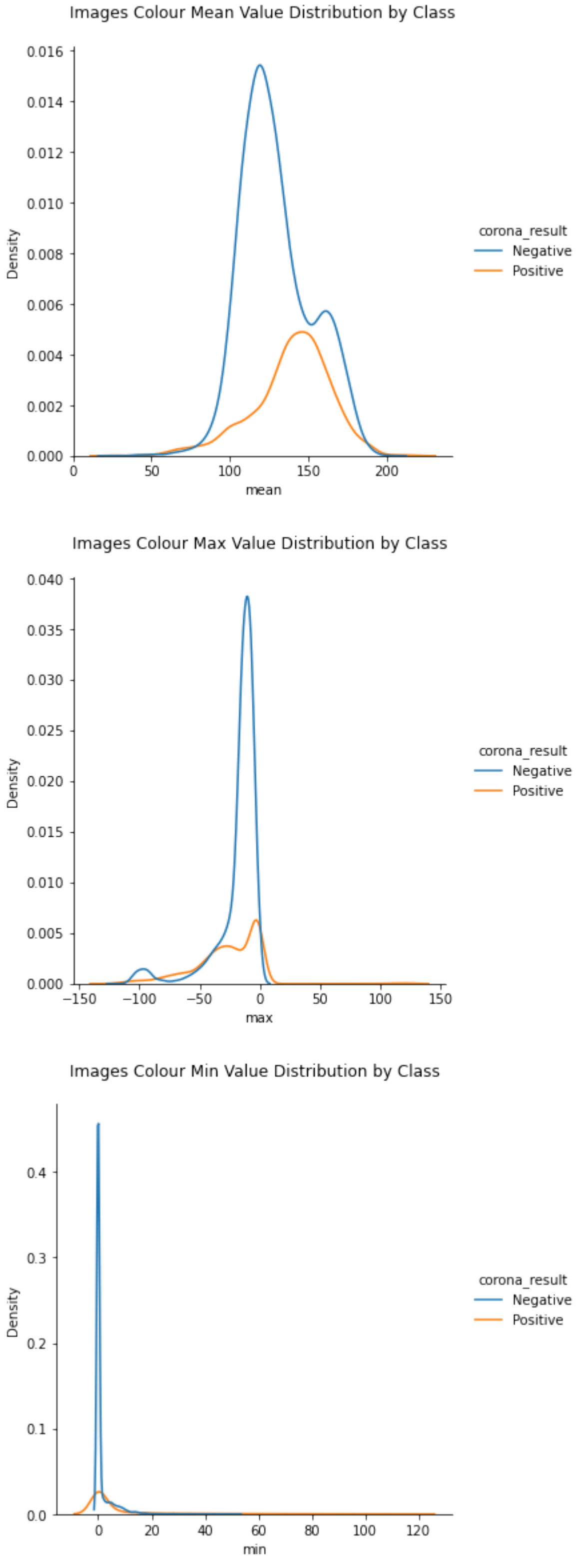
6. Albumentations Visualization

```
def plot_multiple_img(img_matrix_list, title_list, ncols, main_title = ""):

    fig, myaxes = plt.subplots(figsize = (15, 8), nrows = 2, ncols = ncols, squeeze = False)
    fig.suptitle(main_title, fontsize = 18)
    fig.subplots_adjust(wspace = 0.3)
    fig.subplots_adjust(hspace = 0.3)

    for i, (img, title) in enumerate(zip(img_matrix_list, title_list)):
        myaxes[i // ncols][i % ncols].imshow(img)
        myaxes[i // ncols][i % ncols].set_title(title, fontsize = 15)

    plt.show()


chosen_image = cv2.imread("../input/covid19-radiography-database/COVID-19_Radiography_Dataset/COVID/COVID-1002.png")

albumentation_list = [A.RandomFog(p = 1), A.RandomBrightness(p = 1),
                      A.RandomCrop(p = 1,height = 199, width = 199), A.Rotate(p = 1, limit = 90),
                      A.RGBShift(p = 1), A.VerticalFlip(p = 1), A.RandomContrast(limit = 0.5, p = 1)]

img_matrix_list = []
bboxes_list = []
for aug_type in albumentation_list:
    img = aug_type(image = chosen_image)['image']
    img_matrix_list.append(img)

img_matrix_list.insert(0,chosen_image)

titles_list = ["Original", "RandomFog", "RandomBrightness", "RandomCrop", "Rotate", "RGBShift", "VerticalFlip", "RandomContr

plot_multiple_img(img_matrix_list, titles_list, ncols = 4, main_title = "Different Types of Augmentations")
```



7. Image Value Distribution

```
mean_val = []
std_dev_val = []
max_val = []
min_val = []

for i in range(0, samples):
    mean_val.append(data['image'][i].mean())
    std_dev_val.append(np.std(data['image'][i]))
    max_val.append(data['image'][i].max())
    min_val.append(data['image'][i].min())

imageEDA = data.loc[:,['image','corona_result','path']]
imageEDA['mean'] = mean_val
imageEDA['stedev'] = std_dev_val
imageEDA['max'] = max_val
imageEDA['min'] = min_val

imageEDA['subt_mean'] = imageEDA['mean'].mean() - imageEDA['mean']


ax1 = sns.displot(data = imageEDA, x = 'mean', kind="kde", hue = 'corona_result');
plt.title('Images Colour Mean Value Distribution by Class\n', fontsize = 12);

ax2 = sns.displot(data = imageEDA, x = 'max', kind="kde", hue = 'corona_result');
plt.title('\nImages Colour Max Value Distribution by Class\n', fontsize = 12);

ax3 = sns.displot(data = imageEDA, x = 'min', kind="kde", hue = 'corona_result');
plt.title('\nImages Colour Min Value Distribution by Class\n', fontsize = 12);
```

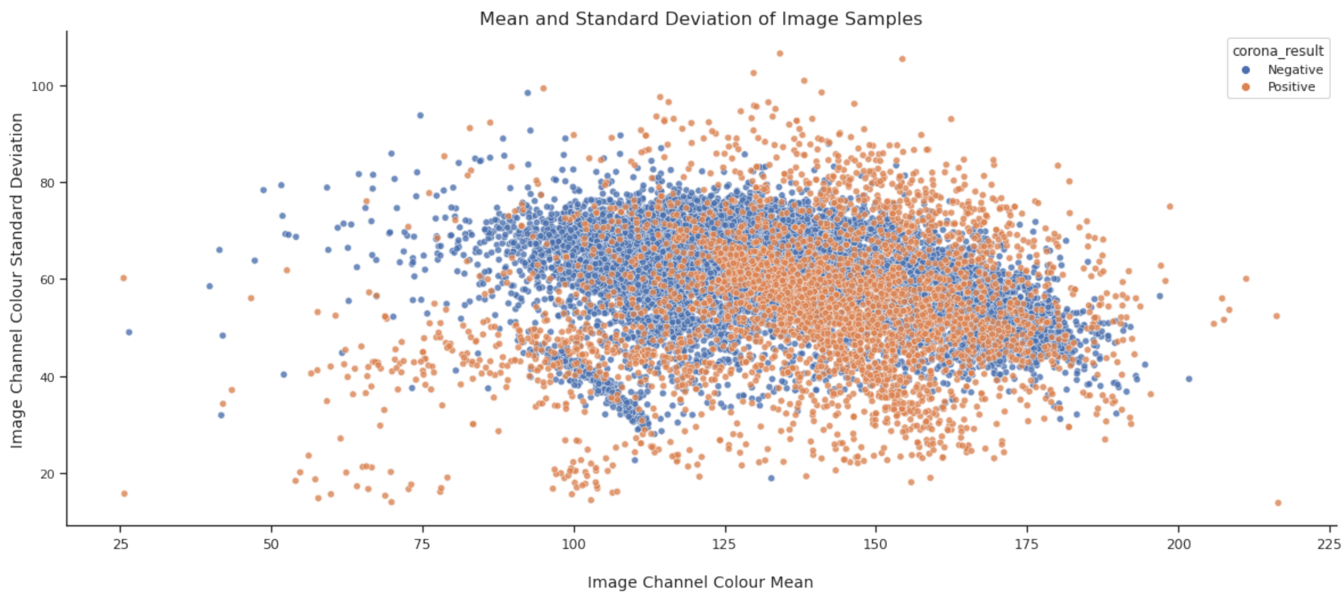


> The Mean vs Density plot insights for pixels:
>
> 1. The max pixel value for Covid Negative cases is greater than 0.014 and less than 0.016.
> 2. The max pixel value for Covid Positive cases is greater than 0.004 & less than 0.006.

> The Max vs Density plot insights for pixels:
>
> 1. The max pixel value for Covid Negative cases is greater than 0.035 and less than 0.040.
> 2. The max pixel value for Covid Positive cases is 0.005.

> The Min vs Density plot insights for pixels:
>
> 1. The max pixel value for Covid Negative cases is greater than 0.4.
> 2. The max pixel value for Covid Positive cases is greater than 0.0 and less than 0.1.

```
plt.figure(figsize = (20, 8))
sns.set(style = "ticks", font_scale = 1)
ax = sns.scatterplot(data = imageEDA, x = "mean", y = imageEDA['stedev'], hue = 'corona_result', alpha = 0.8);
sns.despine(top = True, right = True, left = False, bottom = False)
plt.xticks(rotation = 0, fontsize = 12)
ax.set_xlabel('\nImage Channel Colour Mean', fontsize = 14)
ax.set_ylabel('Image Channel Colour Standard Deviation', fontsize = 14)
plt.title('Mean and Standard Deviation of Image Samples', fontsize = 16);
```

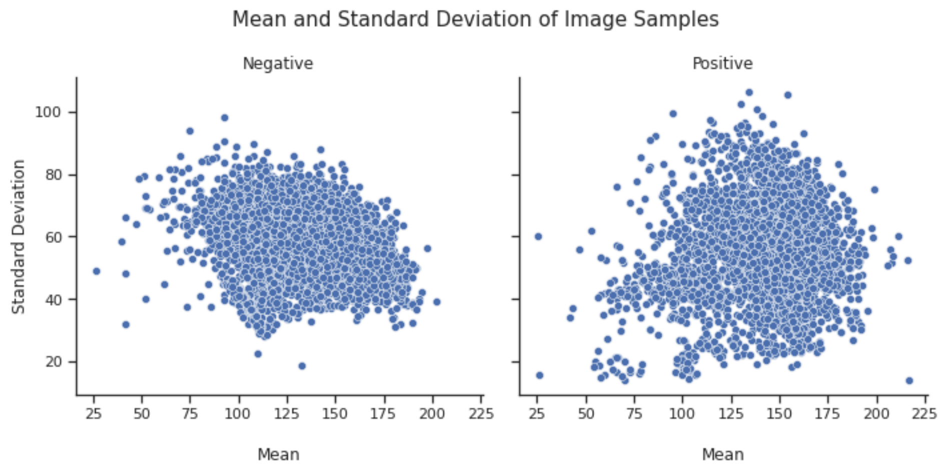


> We observe that there are 2 clusters formed, one for Covid Positive, one for Covid Negative and both have several overlappings. Overlapping Color Mean range: (100 - 175)

> We observe that for pixels having Std Deviation below 30 are all Covid Positive Images (Orange Colored).

```
plt.figure(figsize = (10, 8));
g = sns.FacetGrid(imageEDA, col = "corona_result", height = 5);
g.map_dataframe(sns.scatterplot, x = 'mean', y = 'stedev');
g.set_titles(col_template = "{col_name}", row_template= "{row_name}", size = 12);
g.fig.subplots_adjust(top = .7);
g.fig.suptitle('Mean and Standard Deviation of Image Samples', fontsize = 15);
axes = g.axes.flatten();
axes[0].set_ylabel('Standard Deviation');
for ax in axes:
    ax.set_xlabel('\nMean');
g.fig.tight_layout();
```

```
<Figure size 720x576 with 0 Axes>
```



> Comparing both Scatter plots, we observe that Postivie Samples have outliers (pixel points).

8. Self Insights

Data Modeling

Train Test Split

```
all_data = []

# Storing images and their labels into a list for further Train Test split

for i in range(len(data)):
    image = cv2.imread(data['path'][i])
    image = cv2.resize(image, (70, 70)) / 255.0
    label = 1 if data['corona_result'][i] == "Positive" else 0
    all_data.append([image, label])


x = []
y = []

for image, label in all_data:
    x.append(image)
    y.append(label)

# Converting to Numpy Array
x = np.array(x)
y = np.array(y)

x_train, x_test, y_train, y_test = train_test_split(x, y, test_size = 0.2, random_state = 42)
x_train, x_val, y_train, y_val = train_test_split(x_train, y_train, test_size = 0.1, random_state = 42)

print(x_train.shape, x_test.shape, x_val.shape, y_train.shape, y_test.shape, y_val.shape)
```

```
(9941, 70, 70, 3) (2762, 70, 70, 3) (1105, 70, 70, 3) (9941,) (2762,) (1105,)
```

CNN Model

```
cnn_model = models.Sequential()
cnn_model.add(layers.Conv2D(filters = 128, kernel_size = (3, 3), activation = 'relu', input_shape = (70, 70, 3)))
cnn_model.add(layers.MaxPooling2D((2, 2)))
cnn_model.add(layers.Dropout(0.3))

cnn_model.add(layers.Conv2D(filters = 64, kernel_size = (3, 3), activation = 'relu'))
cnn_model.add(layers.MaxPooling2D((2, 2)))
cnn_model.add(layers.Dropout(0.5))

cnn_model.add(layers.Conv2D(filters = 64, kernel_size = (3, 3), activation = 'relu'))
cnn_model.add(layers.Flatten())
cnn_model.add(layers.Dense(units = 16, activation = 'relu'))
cnn_model.add(layers.Dropout(0.2))

cnn_model.add(layers.Dense(units = 2))

cnn_model.compile(optimizer = 'adam',
           loss = tf.keras.losses.SparseCategoricalCrossentropy(from_logits = True),
           metrics = ['accuracy'])

cnn_model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 68, 68, 128)       3584
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 34, 34, 128)       0
_________________________________________________________________
dropout (Dropout)            (None, 34, 34, 128)       0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 32, 32, 64)        73792
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 16, 16, 64)        0
_________________________________________________________________
```

```
dropout_1 (Dropout)          (None, 16, 16, 64)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 14, 14, 64)        36928
_________________________________________________________________
flatten (Flatten)            (None, 12544)             0
_________________________________________________________________
dense (Dense)                (None, 16)                200720
_________________________________________________________________
dropout_2 (Dropout)          (None, 16)                0
_________________________________________________________________
dense_1 (Dense)              (None, 2)                 34
=================================================================
Total params: 315,058
Trainable params: 315,058
Non-trainable params: 0
_________________________________________________________________
```

```
es = tf.keras.callbacks.EarlyStopping(monitor = 'val_loss', mode = 'min', verbose = 1, patience = 4)

#tf.random.set_seed(42)
history = cnn_model.fit(x_train, y_train,
                        epochs = 50, batch_size = 256,
                        validation_data = (x_val, y_val),
                        callbacks = [es])
```

```
Epoch 1/50
39/39 [==============================] - 10s 75ms/step - loss: 0.5983 - accuracy: 0.7305 - val_loss: 0.5330 - val_accura
Epoch 2/50
39/39 [==============================] - 2s 53ms/step - loss: 0.5099 - accuracy: 0.7330 - val_loss: 0.4462 - val_accurac
Epoch 3/50
39/39 [==============================] - 2s 54ms/step - loss: 0.4548 - accuracy: 0.7336 - val_loss: 0.3705 - val_accurac
Epoch 4/50
39/39 [==============================] - 2s 53ms/step - loss: 0.4100 - accuracy: 0.8087 - val_loss: 0.3403 - val_accurac
Epoch 5/50
39/39 [==============================] - 2s 57ms/step - loss: 0.3683 - accuracy: 0.8456 - val_loss: 0.3147 - val_accurac
Epoch 6/50
39/39 [==============================] - 2s 52ms/step - loss: 0.3441 - accuracy: 0.8642 - val_loss: 0.2937 - val_accurac
Epoch 7/50
39/39 [==============================] - 2s 53ms/step - loss: 0.3256 - accuracy: 0.8743 - val_loss: 0.2735 - val_accurac
Epoch 8/50
39/39 [==============================] - 2s 53ms/step - loss: 0.3040 - accuracy: 0.8917 - val_loss: 0.2549 - val_accurac
Epoch 9/50
39/39 [==============================] - 2s 54ms/step - loss: 0.2909 - accuracy: 0.8971 - val_loss: 0.2394 - val_accurac
Epoch 10/50
39/39 [==============================] - 2s 53ms/step - loss: 0.2799 - accuracy: 0.9016 - val_loss: 0.2399 - val_accurac
Epoch 11/50
39/39 [==============================] - 2s 53ms/step - loss: 0.2667 - accuracy: 0.9097 - val_loss: 0.2278 - val_accurac
Epoch 12/50
39/39 [==============================] - 2s 53ms/step - loss: 0.2605 - accuracy: 0.9100 - val_loss: 0.2207 - val_accurac
Epoch 13/50
39/39 [==============================] - 2s 53ms/step - loss: 0.2459 - accuracy: 0.9159 - val_loss: 0.2047 - val_accurac
Epoch 14/50
39/39 [==============================] - 2s 56ms/step - loss: 0.2281 - accuracy: 0.9273 - val_loss: 0.1909 - val_accurac
Epoch 15/50
39/39 [==============================] - 2s 52ms/step - loss: 0.2213 - accuracy: 0.9296 - val_loss: 0.1822 - val_accurac
Epoch 16/50
39/39 [==============================] - 2s 52ms/step - loss: 0.2065 - accuracy: 0.9347 - val_loss: 0.1775 - val_accurac
Epoch 17/50
39/39 [==============================] - 2s 52ms/step - loss: 0.2123 - accuracy: 0.9301 - val_loss: 0.1719 - val_accurac
Epoch 18/50
39/39 [==============================] - 2s 52ms/step - loss: 0.1914 - accuracy: 0.9394 - val_loss: 0.1706 - val_accurac
Epoch 19/50
39/39 [==============================] - 2s 55ms/step - loss: 0.1817 - accuracy: 0.9442 - val_loss: 0.1740 - val_accurac
Epoch 20/50
39/39 [==============================] - 2s 55ms/step - loss: 0.1781 - accuracy: 0.9453 - val_loss: 0.1612 - val_accurac
Epoch 21/50
39/39 [==============================] - 2s 53ms/step - loss: 0.1694 - accuracy: 0.9478 - val_loss: 0.1627 - val_accurac
Epoch 22/50
39/39 [==============================] - 2s 53ms/step - loss: 0.1712 - accuracy: 0.9449 - val_loss: 0.1564 - val_accurac
Epoch 23/50
39/39 [==============================] - 2s 53ms/step - loss: 0.1583 - accuracy: 0.9515 - val_loss: 0.1621 - val_accurac
Epoch 24/50
39/39 [==============================] - 2s 54ms/step - loss: 0.1594 - accuracy: 0.9484 - val_loss: 0.1610 - val_accurac
Epoch 25/50
39/39 [==============================] - 2s 54ms/step - loss: 0.1490 - accuracy: 0.9539 - val_loss: 0.1552 - val_accurac
Epoch 26/50
39/39 [==============================] - 2s 53ms/step - loss: 0.1460 - accuracy: 0.9563 - val_loss: 0.1402 - val_accurac
Epoch 27/50
39/39 [==============================] - 2s 52ms/step - loss: 0.1328 - accuracy: 0.9611 - val_loss: 0.1499 - val_accurac
Epoch 28/50
39/39 [==============================] - 2s 53ms/step - loss: 0.1256 - accuracy: 0.9624 - val_loss: 0.1265 - val_accurac
Epoch 29/50
39/39 [==============================] - 2s 54ms/step - loss: 0.1215 - accuracy: 0.9664 - val_loss: 0.1281 - val_accurac
```

```
yp_train = cnn_model.predict(x_train)
yp_train = np.argmax(yp_train, axis = 1)

yp_val = cnn_model.predict(x_val)
```

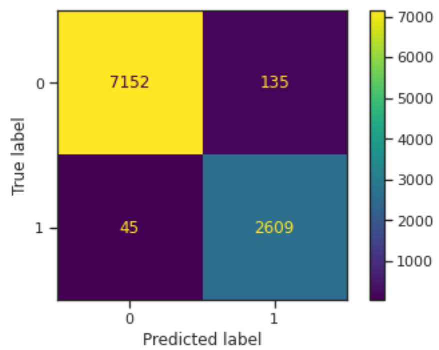
```
yp_val = np.argmax(yp_val, axis = 1)

yp_test = cnn_model.predict(x_test)
yp_test = np.argmax(yp_test, axis = 1)
```

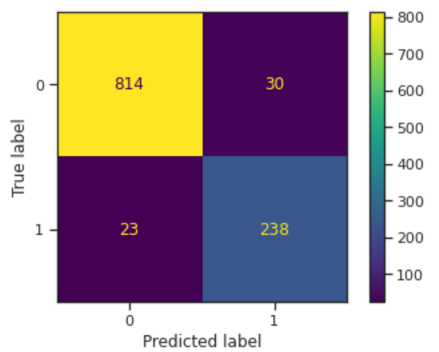
Model Evaluation

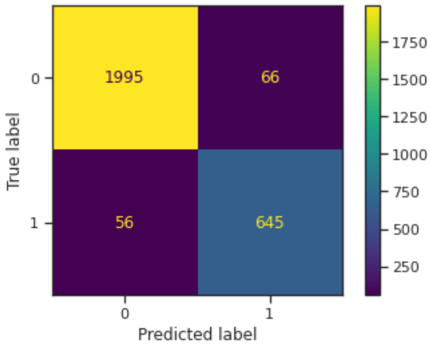
```
def evaluation_parametrics(name, y_train, yp_train, y_val, yp_val, y_test, yp_test):

    print("\n-----------------------------{}-----------------------------\n".format(name))

    cm_train = confusion_matrix(y_train, yp_train)
    t1 = ConfusionMatrixDisplay(cm_train)
    s1 = round((cm_train[0,0]/(cm_train[0,0] + cm_train[0,1])),4)

    print("Classification Report for Train Data\n")
    print(classification_report(y_train, yp_train))
    print("--------------------------------------------------------------------------")
    print("Recall on Train Data: ", round(recall_score(y_train, yp_train),4))
    print("Specificity on Train Data: ", s1)
    print("Accuracy on Train Data: ", round(accuracy_score(y_train, yp_train),4))
    print("Precision on Train Data: ", round(precision_score(y_train, yp_train),4))
    print("F1 Score on Train Data: ", round(f1_score(y_train, yp_train),4))
    print("--------------------------------------------------------------------------")

    cm_val = confusion_matrix(y_val, yp_val)
    t2 = ConfusionMatrixDisplay(cm_val)
    s2 = round((cm_val[0,0]/(cm_val[0,0] + cm_val[0,1])),4)

    print("\nClassification Report for Validation Data\n")
    print(classification_report(y_val, yp_val))
    print("--------------------------------------------------------------------------")
    print("Recall on Val Data: ", round(recall_score(y_val, yp_val),4))
    print("Specificity on Val Data: ", s2)
    print("Accuracy on Val Data: ", round(accuracy_score(y_val, yp_val),4))
    print("Precision on Val Data: ", round(precision_score(y_val, yp_val),4))
    print("F1 Score on Val Data: ", round(f1_score(y_val, yp_val),4))
    print("--------------------------------------------------------------------------")

    cm_test = confusion_matrix(y_test, yp_test)
    t3 = ConfusionMatrixDisplay(cm_test)
    s3 = round((cm_test[0,0]/(cm_test[0,0] + cm_test[0,1])),4)

    print("\nClassification Report for Test Data\n")
    print(classification_report(y_test, yp_test))
    print("--------------------------------------------------------------------------")
    print("Recall on Test Data: ", round(recall_score(y_test, yp_test), 4))
    print("Specificity on Test Data: ", s3)
    print("Accuracy on Test Data: ", round(accuracy_score(y_test, yp_test), 4))
    print("Precision on Test Data: ", round(precision_score(y_test, yp_test), 4))
    print("F1 Score Test Data: ", round(f1_score(y_test, yp_test), 4))
    print("--------------------------------------------------------------------------")

    t1.plot()
    t2.plot()
    t3.plot()
```

```
evaluation_parametrics("Convolution Neural Network", y_train, yp_train, y_val, yp_val, y_test, yp_test)
```

```
-----------------------------Convolution Neural Network-----------------------------

Classification Report for Train Data

              precision    recall  f1-score   support

           0       0.99      0.98      0.99      7287
           1       0.95      0.98      0.97      2654

    accuracy                           0.98      9941
   macro avg       0.97      0.98      0.98      9941
weighted avg       0.98      0.98      0.98      9941

--------------------------------------------------------------------------
Recall on Train Data:  0.983
Specificity on Train Data:  0.9815
Accuracy on Train Data:  0.9819
Precision on Train Data:  0.9508
F1 Score on Train Data:  0.9667
--------------------------------------------------------------------------

Classification Report for Validation Data

              precision    recall  f1-score   support

           0       0.97      0.96      0.97       844
           1       0.89      0.91      0.90       261

    accuracy                           0.95      1105
   macro avg       0.93      0.94      0.93      1105
weighted avg       0.95      0.95      0.95      1105

--------------------------------------------------------------------------
Recall on Val Data:  0.9119
Specificity on Val Data:  0.9645
Accuracy on Val Data:  0.952
Precision on Val Data:  0.8881
F1 Score on Val Data:  0.8998
--------------------------------------------------------------------------

Classification Report for Test Data

              precision    recall  f1-score   support

           0       0.97      0.97      0.97      2061
           1       0.91      0.92      0.91       701

    accuracy                           0.96      2762
   macro avg       0.94      0.94      0.94      2762
weighted avg       0.96      0.96      0.96      2762

--------------------------------------------------------------------------
Recall on Test Data:  0.9201
Specificity on Test Data:  0.968
Accuracy on Test Data:  0.9558
Precision on Test Data:  0.9072
F1 Score Test Data:  0.9136
--------------------------------------------------------------------------
```



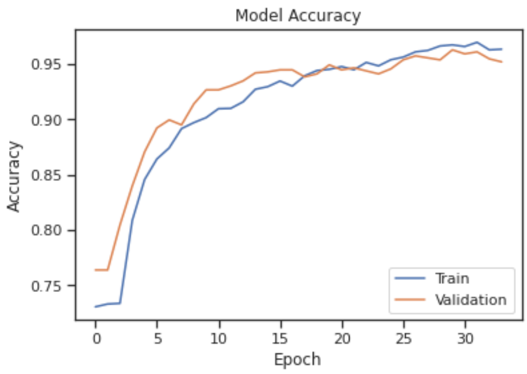




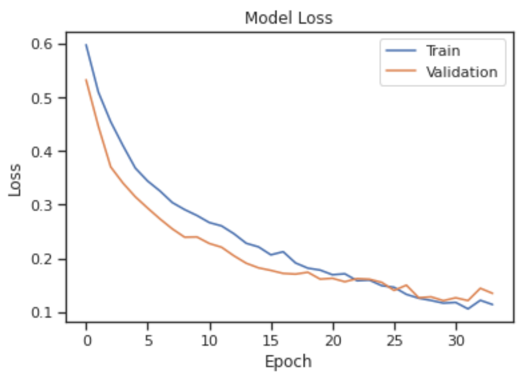

```
# list all data in history

print(history.history.keys())
```

```
dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy'])
```

```
# Summarize History for Accuracy

plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('Model Accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Validation'], loc = 'lower right')
plt.show()
```

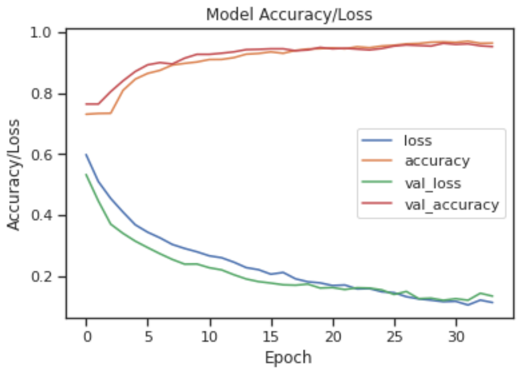



```
# Summarize History for Loss

plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('Model Loss')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend(['Train', 'Validation'], loc = 'upper right')
plt.show()
```




```
# Accuracy Loss Graph

pd.DataFrame(history.history).plot()
plt.title('Model Accuracy/Loss')
plt.ylabel('Accuracy/Loss')
```

```
plt.xlabel('Epoch')
plt.show()
```



> We observe that Train & Validation Accuracy's Curve slightly overlap and same with Loss Curve.

> Hence, Overfitting is avoided, this is possible because of Dropout Regularization & Early Stopping Metrics.

Image Analysis using Grad-CAM

Config- Parameters

```
model_builder = keras.applications.xception.Xception
img_size = (299, 299)
preprocess_input = keras.applications.xception.preprocess_input
decode_predictions = keras.applications.xception.decode_predictions
imag = []

last_conv_layer_name = "block14_sepconv2_act"

# Reading 2 Covid & 2 Normal Images for Grad-Cam Analysis

img_path = ["../input/covid19-radiography-database/COVID-19_Radiography_Dataset/COVID/COVID-1002.png",
            "../input/covid19-radiography-database/COVID-19_Radiography_Dataset/COVID/COVID-101.png",
            "../input/covid19-radiography-database/COVID-19_Radiography_Dataset/Normal/Normal-10004.png",
           "../input/covid19-radiography-database/COVID-19_Radiography_Dataset/Normal/Normal-10002.png"]
```

Grad - CAM Algorithm

```
# To Get Image into numpy array

def get_img_array(img_path, size):
    img = keras.preprocessing.image.load_img(img_path, target_size = size)
    array = keras.preprocessing.image.img_to_array(img)
    array = np.expand_dims(array, axis = 0)
    return array

# Top create heatmaps for the samples

def make_gradcam_heatmap(img_array, model, last_conv_layer_name, pred_index = None):
    grad_model = tf.keras.models.Model([model.inputs], [model.get_layer(last_conv_layer_name).output, model.output])

    with tf.GradientTape() as tape:
        last_conv_layer_output, preds = grad_model(img_array)
        if pred_index is None:
            pred_index = tf.argmax(preds[0])
        class_channel = preds[:, pred_index]

    grads = tape.gradient(class_channel, last_conv_layer_output)
    pooled_grads = tf.reduce_mean(grads, axis=(0, 1, 2))

    last_conv_layer_output = last_conv_layer_output[0]
    heatmap = last_conv_layer_output @ pooled_grads[..., tf.newaxis]
    heatmap = tf.squeeze(heatmap)
    heatmap = tf.maximum(heatmap, 0) / tf.math.reduce_max(heatmap)
    return heatmap.numpy()
```

Heatmap

```
# Storing Heatmap values into list

covid_noncovid_heatmap = []

for i in img_path:
    img_array = preprocess_input(get_img_array(i, size = img_size))
    model = model_builder(weights = "imagenet")
    model.layers[-1].activation = None
    preds = model.predict(img_array)
    heatmap = make_gradcam_heatmap(img_array, model, last_conv_layer_name)
    covid_noncovid_heatmap.append(heatmap)
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/xception/xception_weights_tf_dim_orde
91889664/91884032 [==============================] - 1s 0us/step
91897856/91884032 [==============================] - 1s 0us/step
```

Creating a Superimposed Viz

```
# To Display GradCAM output for the samples

def save_and_display_gradcam(img_path, heatmap, cam_path = "cam.jpg", alpha = 0.4):
    img = keras.preprocessing.image.load_img(img_path)
    img = keras.preprocessing.image.img_to_array(img)

    heatmap = np.uint8(255 * heatmap)

    jet = cm.get_cmap("jet")
    jet_colors = jet(np.arange(256))[:, :3]
    jet_heatmap = jet_colors[heatmap]
    jet_heatmap = keras.preprocessing.image.array_to_img(jet_heatmap)
    jet_heatmap = jet_heatmap.resize((img.shape[1], img.shape[0]))
    jet_heatmap = keras.preprocessing.image.img_to_array(jet_heatmap)

    superimposed_img = jet_heatmap * alpha + img
    superimposed_img = keras.preprocessing.image.array_to_img(superimposed_img)
    superimposed_img.save(cam_path)

    imag.append(cv2.imread(img_path))
    imag.append(cv2.imread("./cam.jpg"))


for i in range(len(img_path)):
    save_and_display_gradcam(img_path[i], covid_noncovid_heatmap[i])


titles_list = ["Positive-1",'Positive-1 Grad','Positive-2','Positive-2 Grad','Negative-1','Negative-1 Grad','Negative-2','Ne

plot_multiple_img(imag, titles_list, ncols = 4, main_title = "GRAD-CAM COVID-19 Image Analysis")
```