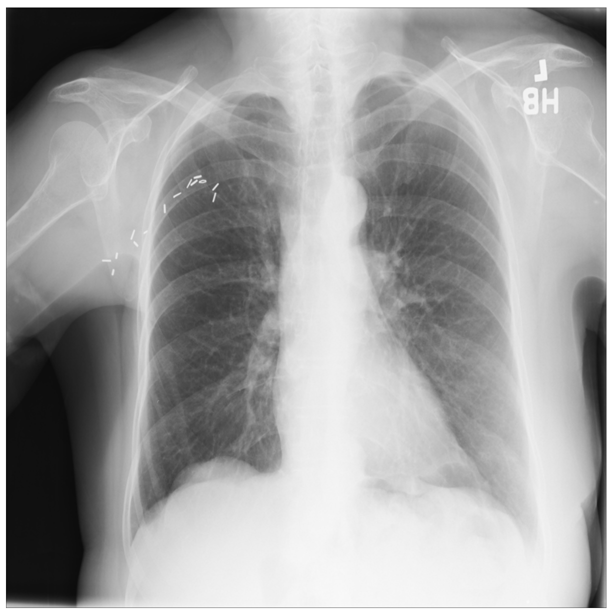
AI for Medicine Course 1 Week 1 lecture exercises

Data Exploration

In the first assignment of this course, you will work with chest x-ray images taken from the public [ChestX-ray8 dataset (https://arxiv.org/abs/1705.02315)](https://arxiv.org/abs/1705.02315). In this notebook, you'll get a chance to explore this dataset and familiarize yourself with some of the techniques you'll use in the first graded assignment.



The first step before jumping into writing code for any machine learning project is to explore your data. A standard Python package for analyzing and manipulating data is [pandas (https://pandas.pydata.org/docs/)](https://pandas.pydata.org/docs/).

With the next two code cells, you'll import `pandas` and a package called `numpy` for numerical manipulation, then use `pandas` to read a csv file into a dataframe and print out the first few rows of data.

In [1]:
```
# Import necessary packages
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
import os
import seaborn as sns
sns.set()
```

In [3]:
```
# Read csv file containing training datadata
train_df = pd.read_csv("nih/train-small.csv")
# Print first 5 rows
print(f'There are {train_df.shape[0]} rows and {train_df.shape[1]} columns in this
train_df.head()
```

```
There are 1000 rows and 16 columns in this data frame
```

Out[3]:

	Image	Atelectasis	Cardiomegaly	Consolidation	Edema	Effusion	Emphysema	Fibr
0	00008270_015.png	0	0	0	0	0	0	
1	00029855_001.png	1	0	0	0	1	0	
2	00001297_000.png	0	0	0	0	0	0	
3	00012359_002.png	0	0	0	0	0	0	
4	00017951_001.png	0	0	0	0	0	0	

Have a look at the various columns in this csv file. The file contains the names of chest x-ray images ("Image" column) and the columns filled with ones and zeros identify which diagnoses were given based on each x-ray image.

Data types and null values check

Run the next cell to explore the data types present in each column and whether any null values exist in the data.

In [4]:
```
# Look at the data type of each column and whether null values are present
train_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1000 entries, 0 to 999
Data columns (total 16 columns):
Image                  1000 non-null object
Atelectasis            1000 non-null int64
Cardiomegaly           1000 non-null int64
Consolidation          1000 non-null int64
Edema                  1000 non-null int64
Effusion               1000 non-null int64
Emphysema              1000 non-null int64
Fibrosis               1000 non-null int64
Hernia                 1000 non-null int64
Infiltration           1000 non-null int64
Mass                   1000 non-null int64
Nodule                 1000 non-null int64
PatientId              1000 non-null int64
Pleural_Thickening     1000 non-null int64
Pneumonia              1000 non-null int64
Pneumothorax           1000 non-null int64
dtypes: int64(15), object(1)
memory usage: 125.1+ KB
```

Unique IDs check

"PatientId" has an identification number for each patient. One thing you'd like to know about a medical dataset like this is if you're looking at repeated data for certain patients or whether each image represents a different person.

In [5]:
```
print(f"The total patient ids are {train_df['PatientId'].count()}, from those the
```

```
The total patient ids are 1000, from those the unique ids are 928
```

In [11]:
```
len(train_df['PatientId'].unique())
```

Out[11]:
```
928
```

As you can see, the number of unique patients in the dataset is less than the total number so there must be some overlap. For patients with multiple records, you'll want to make sure they do not show up in both training and test sets in order to avoid data leakage (covered later in this week's lectures).

Explore data labels

Run the next two code cells to create a list of the names of each patient condition or disease.

In [18]:
```
len(train_df.columns)
```

Out[18]:
```
16
```

In [16]:
```
columns = train_df.keys()
columns = list(columns)
print(columns)
```

```
['Image', 'Atelectasis', 'Cardiomegaly', 'Consolidation', 'Edema', 'Effusion',
'Emphysema', 'Fibrosis', 'Hernia', 'Infiltration', 'Mass', 'Nodule', 'PatientI
d', 'Pleural_Thickening', 'Pneumonia', 'Pneumothorax']
```

In [17]:
```
# Remove unnecesary elements
columns.remove('Image')
columns.remove('PatientId')
# Get the total classes
print(f"There are {len(columns)} columns of labels for these conditions: {columns}
```

```
There are 14 columns of labels for these conditions: ['Atelectasis', 'Cardiome
galy', 'Consolidation', 'Edema', 'Effusion', 'Emphysema', 'Fibrosis', 'Herni
a', 'Infiltration', 'Mass', 'Nodule', 'Pleural_Thickening', 'Pneumonia', 'Pneu
mothorax']
```

In [21]:
```
train_df['Mass'].sum()
```

Out[21]:
```
45
```

Run the next cell to print out the number of positive labels (1's) for each condition

In [19]:
```
# Print out the number of positive labels for each class
for column in columns:
    print(f"The class {column} has {train_df[column].sum()} samples")
```

```
The class Atelectasis has 106 samples
The class Cardiomegaly has 20 samples
The class Consolidation has 33 samples
The class Edema has 16 samples
The class Effusion has 128 samples
The class Emphysema has 13 samples
The class Fibrosis has 14 samples
The class Hernia has 2 samples
The class Infiltration has 175 samples
The class Mass has 45 samples
The class Nodule has 54 samples
The class Pleural_Thickening has 21 samples
The class Pneumonia has 10 samples
The class Pneumothorax has 38 samples
```

Have a look at the counts for the labels in each class above. Does this look like a balanced dataset?

Data Visualization

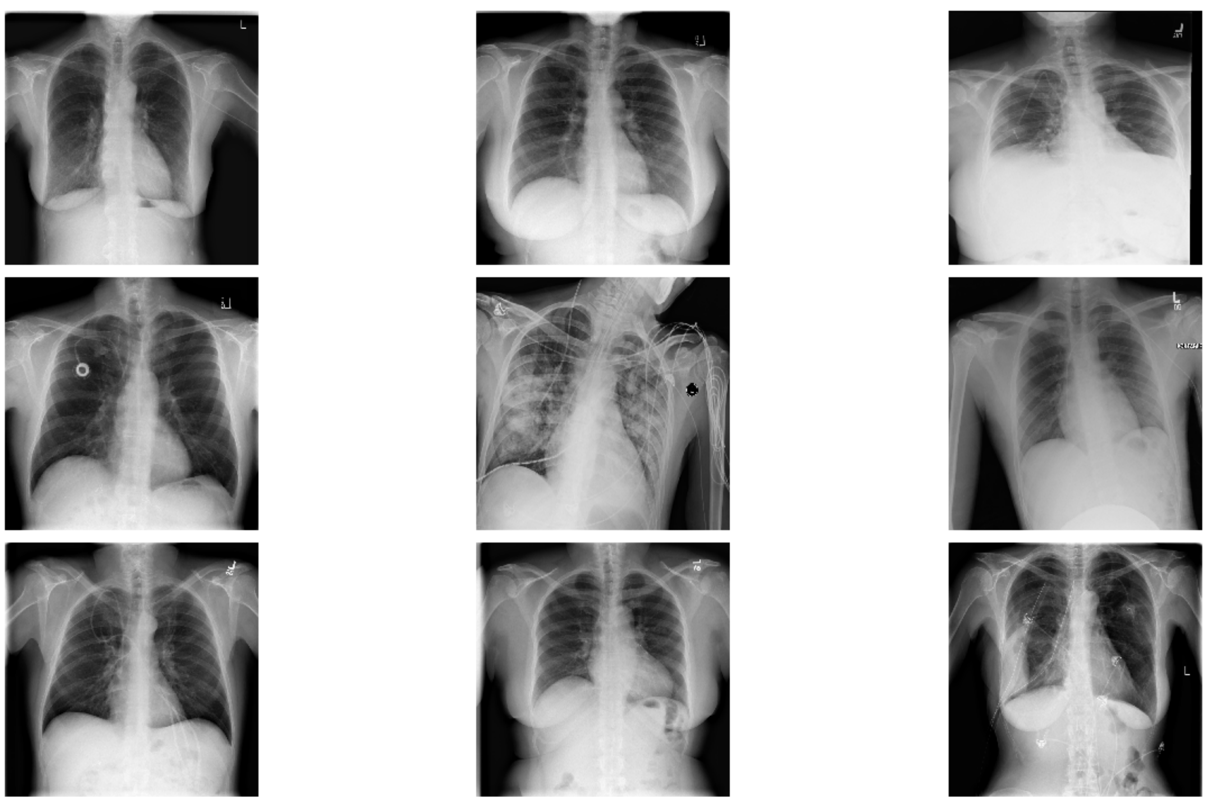
Using the image names listed in the csv file, you can retrieve the image associated with each row of data in your dataframe.

Run the cell below to visualize a random selection of images from the dataset.

In [25]:

```
# Extract numpy values from Image column in data frame
images = train_df['Image'].values

# Extract 9 random images from it
random_images = [np.random.choice(images) for i in range(9)]

# Location of the image dir
img_dir = 'nih/images-small/'

print('Display Random Images')

# Adjust the size of your images
plt.figure(figsize=(20,10))

# Iterate and plot random images
for i in range(9):
    plt.subplot(3, 3, i + 1)
    img = plt.imread(img_dir+'/'+random_images[i])
    plt.imshow(img, cmap='gray')
    plt.axis('off')

# Adjust subplot parameters to give specified padding
plt.tight_layout()
```

```
Display Random Images
```



In [24]:

```
os.path.join(img_dir, random_images[0])
```

Out[24]:

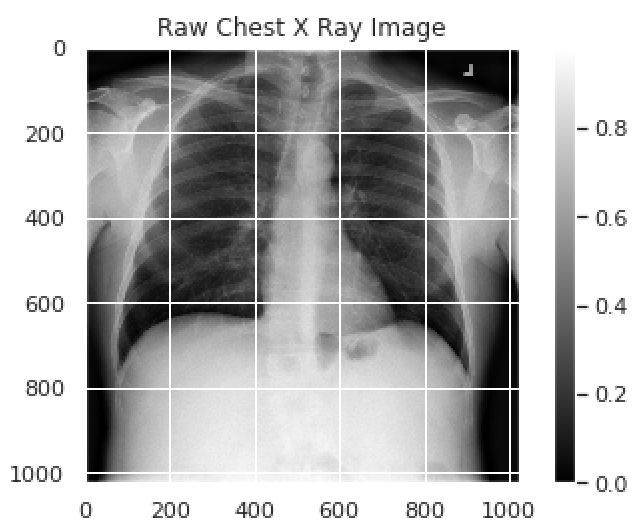
```
'nih/images-small/00017840_000.png'
```

Investigate a single image

Run the cell below to look at the first image in the dataset and print out some details of the image contents.

In [26]:
```
# Get the first image that was listed in the train_df dataframe
sample_img = train_df.Image[0]
raw_image = plt.imread(os.path.join(img_dir, sample_img))
plt.imshow(raw_image, cmap='gray')
plt.colorbar()
plt.title('Raw Chest X Ray Image')
print(f"The dimensions of the image are {raw_image.shape[0]} pixels width and {raw
print(f"The maximum pixel value is {raw_image.max():.4f} and the minimum is {raw_i
print(f"The mean value of the pixels is {raw_image.mean():.4f} and the standard de
```

```
The dimensions of the image are 1024 pixels width and 1024 pixels height, one
single color channel
The maximum pixel value is 0.9804 and the minimum is 0.0000
The mean value of the pixels is 0.4796 and the standard deviation is 0.2757
```

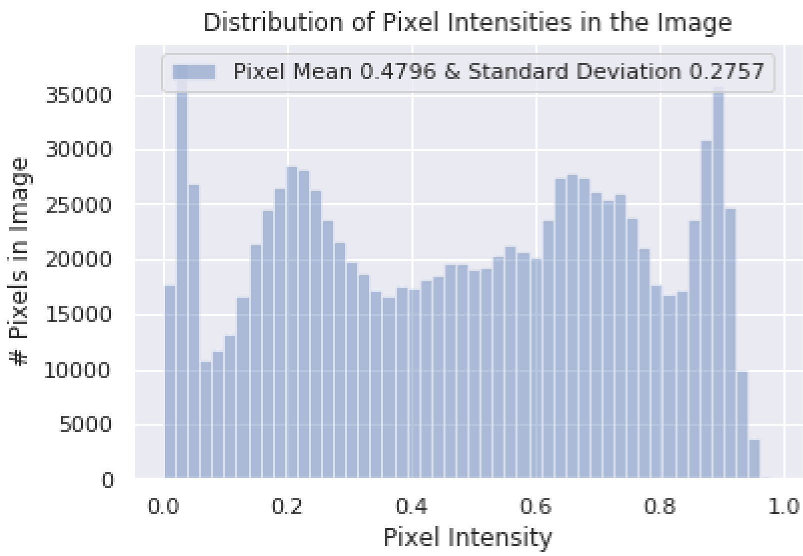


Investigate pixel value distribution

Run the cell below to plot up the distribution of pixel values in the image shown above.

In [27]:
```
# Plot a histogram of the distribution of the pixels
sns.distplot(raw_image.ravel(),
             label=f'Pixel Mean {np.mean(raw_image):.4f} & Standard Deviation {np.
plt.legend(loc='upper center')
plt.title('Distribution of Pixel Intensities in the Image')
plt.xlabel('Pixel Intensity')
plt.ylabel('# Pixels in Image')
```

Out[27]:
```
Text(0, 0.5, '# Pixels in Image')
```



In [30]:
```
raw_image.ravel()
```

Out[30]:
```
array([0.84705883, 0.8352941 , 0.8235294 , ..., 0.14509805, 0.14509805,
       0.07843138], dtype=float32)
```

Image Preprocessing in Keras

Before training, you'll first modify your images to be better suited for training a convolutional neural network. For this task you'll use the Keras [ImageDataGenerator (https://keras.io/preprocessing/image/)](https://keras.io/preprocessing/image/) function to perform data preprocessing and data augmentation.

Run the next two cells to import this function and create an image generator for preprocessing.

In [31]:
```
# Import data generator from keras
from keras.preprocessing.image import ImageDataGenerator
```

```
Using TensorFlow backend.
```

In [32]:
```
# Normalize images
image_generator = ImageDataGenerator(
    samplewise_center=True, #Set each sample mean to 0.
    samplewise_std_normalization= True # Divide each input by its standard deviati
)
```

Standardization

The `image_generator` you created above will act to adjust your image data such that the new mean of the data will be zero, and the standard deviation of the data will be 1.

In other words, the generator will replace each pixel value in the image with a new value calculated by subtracting the mean and dividing by the standard deviation.

$$\frac{x_i - \mu}{\sigma}$$

Run the next cell to pre-process your data using the `image_generator`. In this step you will also be reducing the image size down to 320x320 pixels.

In [33]:
```
# Flow from directory with specified batch size and target image size
generator = image_generator.flow_from_dataframe(
        dataframe=train_df,
        directory="nih/images-small/",
        x_col="Image", # features
        y_col= ['Mass'], # labels
        class_mode="raw", # 'Mass' column should be in train_df
        batch_size= 1, # images per batch
        shuffle=False, # shuffle the rows or not
        target_size=(320,320) # width and height of output image
)
```

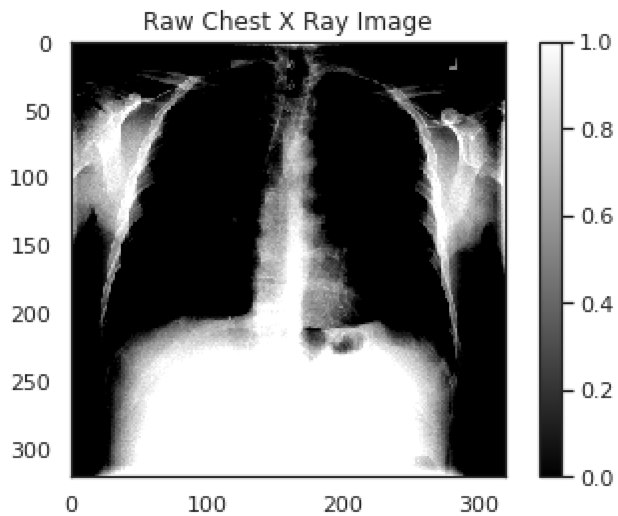
```
Found 1000 validated image filenames.
```

Run the next cell to plot up an example of a pre-processed image

In [36]:
```
# Plot a processed image
sns.set_style("white")
generated_image, label = generator.__getitem__(0)
plt.imshow(generated_image[0], cmap='gray')
plt.colorbar()
plt.title('Raw Chest X Ray Image')
print(f"The dimensions of the image are {generated_image.shape[1]} pixels width an
print(f"The maximum pixel value is {generated_image.max():.4f} and the minimum is
print(f"The mean value of the pixels is {generated_image.mean():.4f} and the stand
```

```
Clipping input data to the valid range for imshow with RGB data ([0..1] for fl
oats or [0..255] for integers).
```

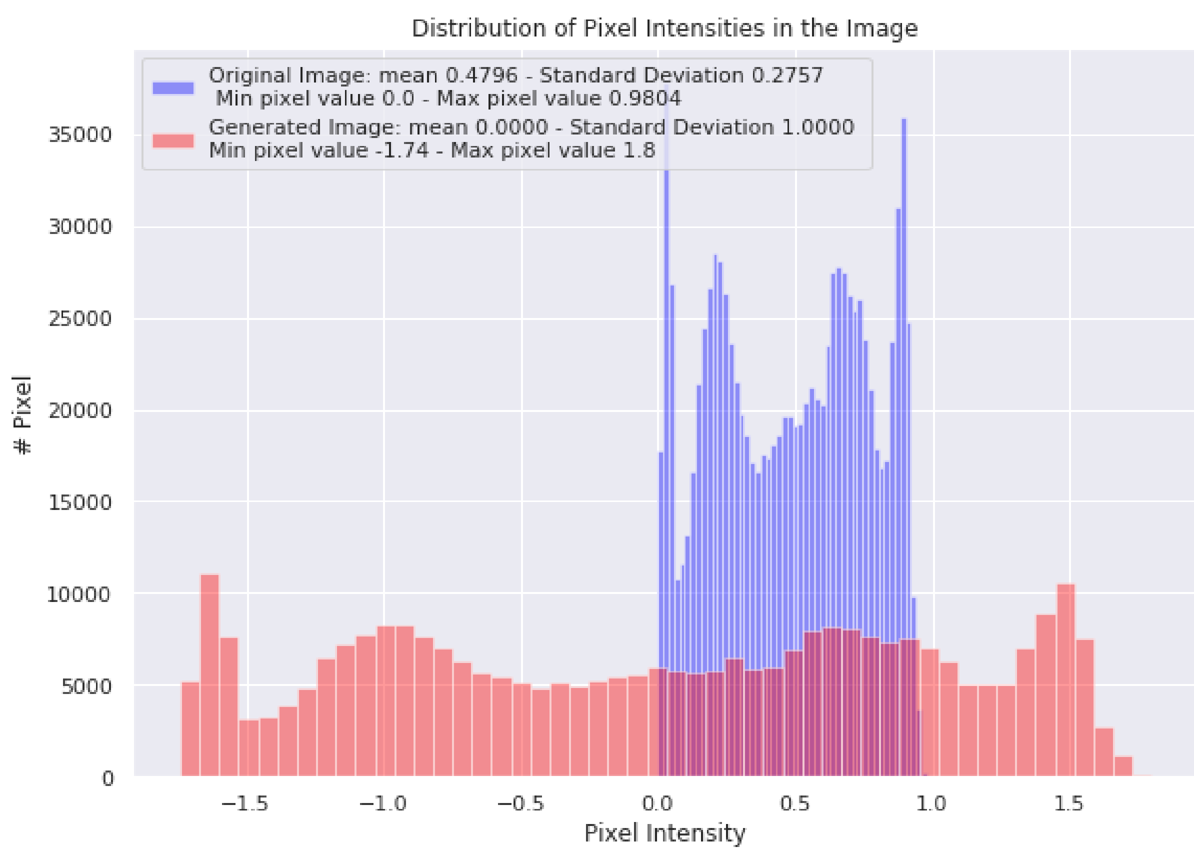
```
The dimensions of the image are 320 pixels width and 320 pixels height
The maximum pixel value is 1.7999 and the minimum is -1.7404
The mean value of the pixels is 0.0000 and the standard deviation is 1.0000
```



Run the cell below to see a comparison of the distribution of pixel values in the new pre-processed image versus the raw image.

In [37]:
```
# Include a histogram of the distribution of the pixels
sns.set()
plt.figure(figsize=(10, 7))

# Plot histogram for original iamge
sns.distplot(raw_image.ravel(),
             label=f'Original Image: mean {np.mean(raw_image):.4f} - Standard Devi
             f'Min pixel value {np.min(raw_image):.4} - Max pixel value {np.max(ra
             color='blue',
             kde=False)

# Plot histogram for generated image
sns.distplot(generated_image[0].ravel(),
             label=f'Generated Image: mean {np.mean(generated_image[0]):.4f} - Sta
             f'Min pixel value {np.min(generated_image[0]):.4} - Max pixel value {
             color='red',
             kde=False)

# Place legends
plt.legend()
plt.title('Distribution of Pixel Intensities in the Image')
plt.xlabel('Pixel Intensity')
plt.ylabel('# Pixel')
```

Out[37]:
```
Text(0, 0.5, '# Pixel')
```



That's it for this exercise, you should now be a bit more familiar with the dataset you'll be using in this week's assignment!

In [ ]:

```

```