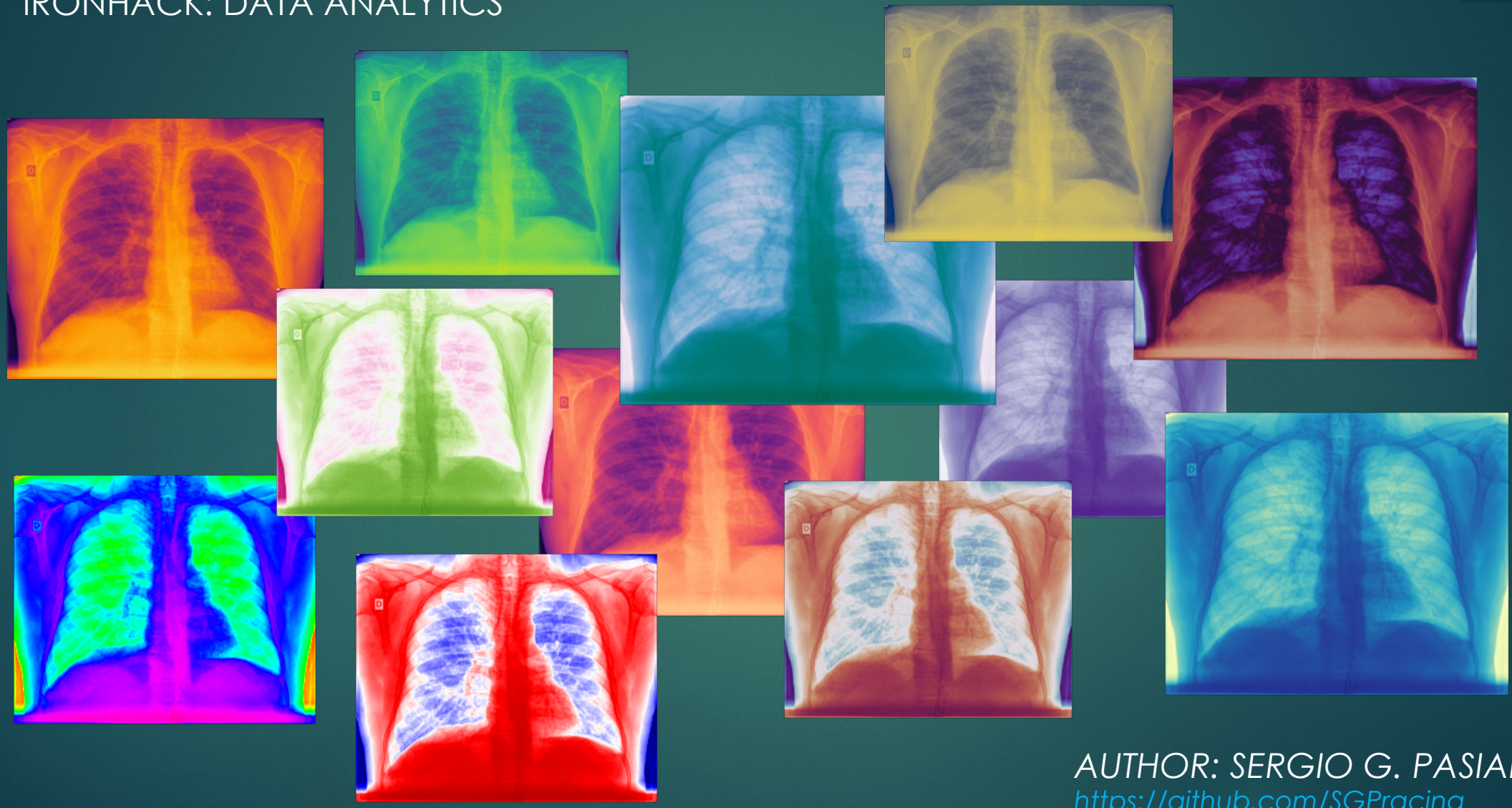
PROJECT X-RAY

IRONHACK: DATA ANALYTICS



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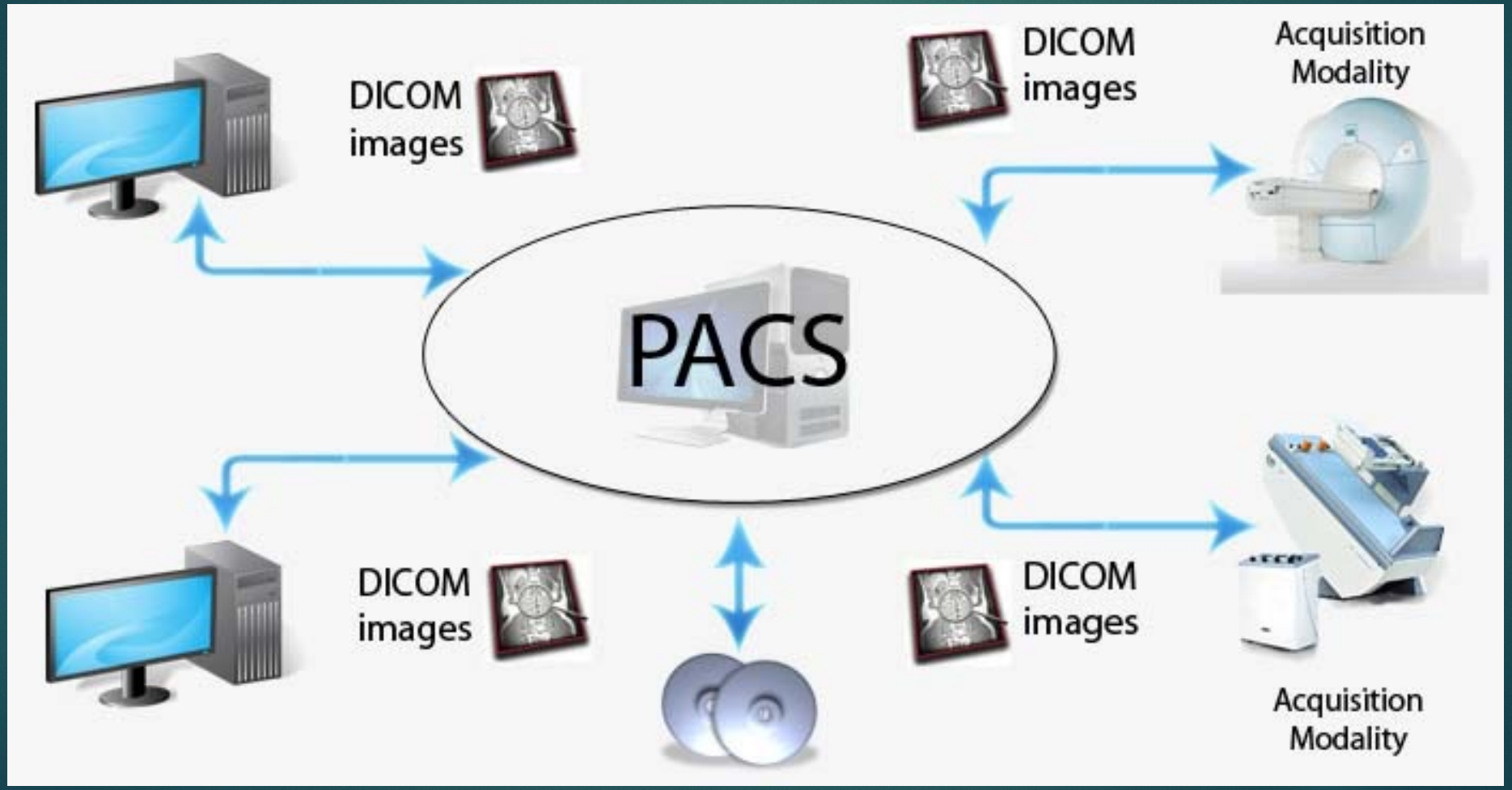
https://github.com/SGPracing

Link: https://www.kaggle.com/competitions/unifesp-x-ray-body-part-classifier

- **Objective:**
  - to predict the body part from a given X-ray
- **Data:**
  - Sets of images in DICOM format;
  - "train.csv" file, with the following information :
    - 'SOPInstanceUID': image identification (from metadata)
    - 'Target': label (body part): **21 labels**

Why solving this problem matters?

Picture **A**rchiving and **C**ommunication **S**ystem



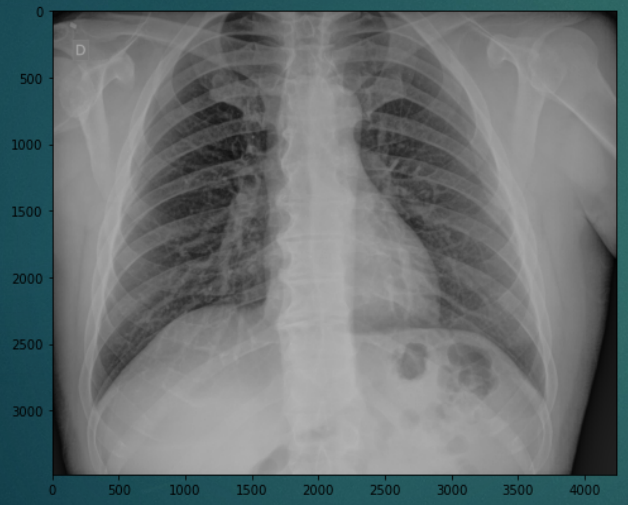
Why solving this problem matters?

Proc Description	Study Date Time	Image Count	Modality	Status
			CR	
JOELHO: AP. + LAT...	11/05/2021 19:02:59	11	CR	Complete
PERNA	11/05/2021 18:53:00	0	CR	Scheduled
QUADRIL - ARTICU...	11/05/2021 18:53:00	0	CR	Scheduled
RAIO X DE TORN...	11/05/2021 18:53:00	0	CR	Scheduled
COXA	11/05/2021 18:52:00	0	CR	Scheduled
BACIA	11/05/2021 18:52:00	0	CR	Scheduled

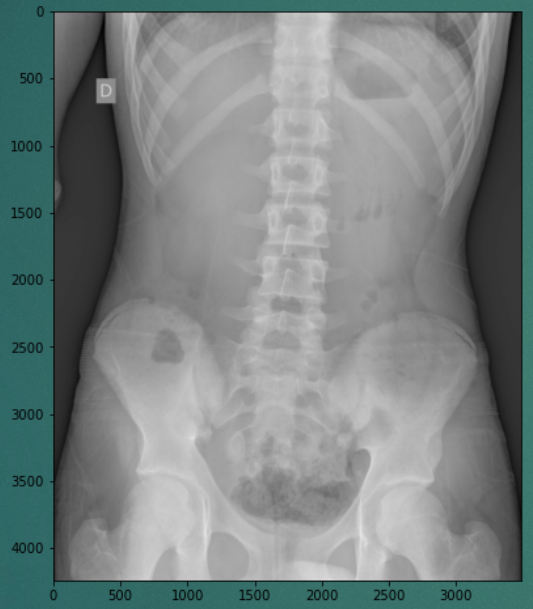
- Several X-rays for the same patient are entered in the system by the receptionist
- Technician opens the knee study and execute all the examens under the same description
- All images (exams) from different body parts are stored within the "knee" study
- It may cause problems for Radiologist to make the report
- Impairs comparison with older exams
- The empty (no images) studies remain with an open status (Schedule), which trigger further problems

It should be a very simple task…

Chest

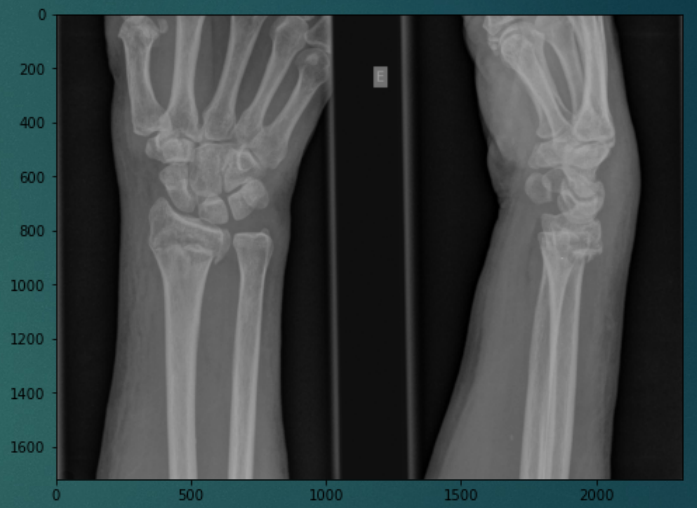


Abdominal

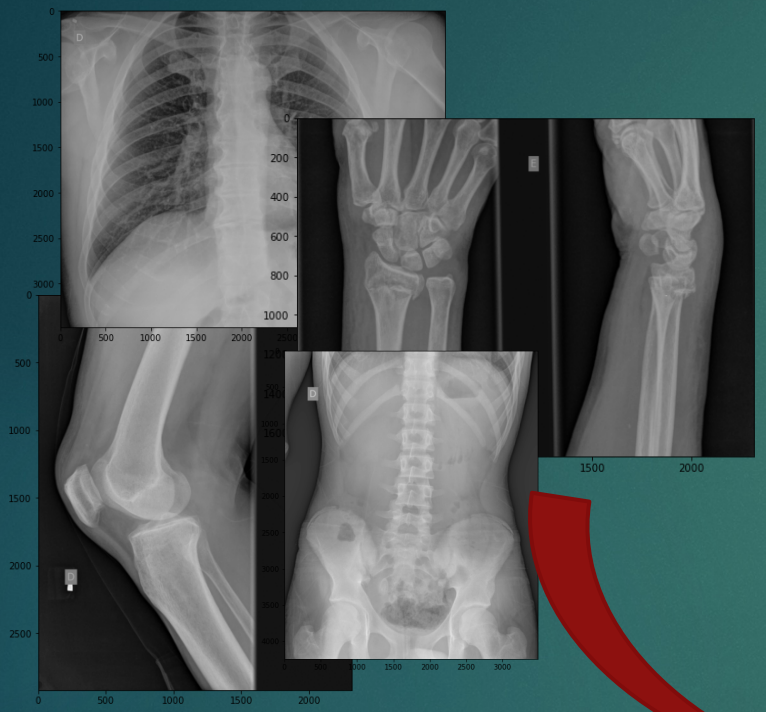


Knee

Wrist



… but it is not that simple…

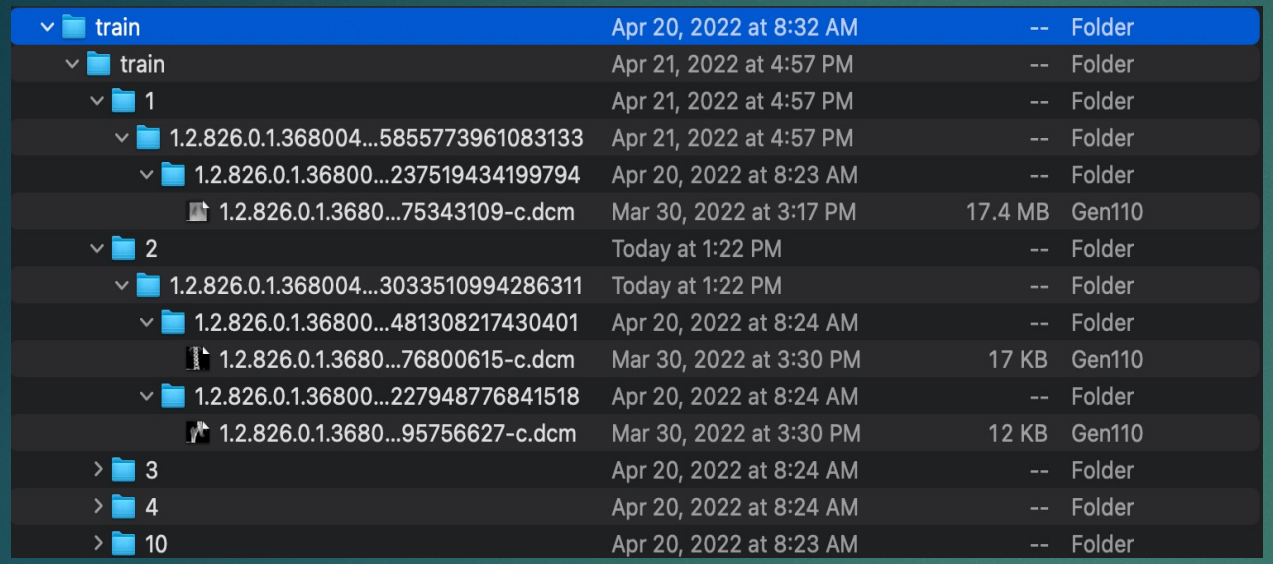


```
array([[140, 144, 143, ...,  51,  50,  50],
       [140, 138, 138, ...,  41,  40,  39],
       [135, 138, 141, ...,  36,  35,  38],
       ...,
       [ 49,  50,  48, ...,  34,  34,  36],
       [ 51,  50,  49, ...,  38,  34,  33],
       [ 53,  51,  50, ...,  35,  35,  36]],
```

… and several challenges were in the way

- Heavy files (train image files approx. 22GB):
  - How to store the transformed images (numpy arrays)
- Load and read the image inside the interface:
  - type of image files (DICOM)
  - decoder (pydicom)
- Image contrast display
- Matching image ID, label from dataframe with image itself
- Image sizing
- Transformation and classification algorithms for images

Image loading and visualization




```
1 from pathlib import Path
2
```

executed in 8ms, finished 13:07:41 2022-05-01

```
1 images_train = Path().cwd().glob("**/train/**/*.dcm")
2 img_train_path_lst = [path for path in images_train]
3
```

executed in 5.39s, finished 13:07:47 2022-05-01

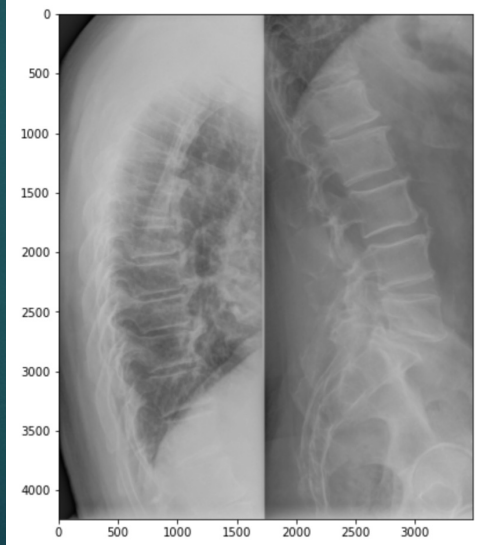
Image Loading & Visualization

```python
import numpy as np
import pydicom
from pydicom.pixel_data_handlers.util import apply_voi_lut

import matplotlib.pyplot as plt
%matplotlib inline


def read_xray(path, voi_lut = True, fix_monochrome = True):
    dicom = pydicom.read_file(path)

    # VOI LUT (if available by DICOM device) is used to transform raw DICOM data to "human-friendly" vi
    if voi_lut:
        data = apply_voi_lut(dicom.pixel_array, dicom)
    else:
        data = dicom.pixel_array

    # depending on this value, X-ray may look inverted - fix that:
    if fix_monochrome and dicom.PhotometricInterpretation == "MONOCHROME1":
        data = np.amax(data) - data

    data = data - np.min(data)
    data = data / np.max(data)
    data = (data * 255).astype(np.uint8)

    return data

```

executed in 18ms, finished 13:10:27 2022-05-01

```python
data = read_xray(img_train_lst[100])
plt.figure(figsize=(8, 8))
plt.imshow(data, 'gray');

```

executed in 5.49s, finished 13:10:59 2022-05-01




```python
data
```

executed in 10ms, finished 13:11:03 2022-05-01

```
array([[ 41,  41,  41, ..., 137, 144, 141],
       [ 41,  41,  41, ..., 136, 137, 138],
       [ 41,  41,  41, ..., 139, 141, 141],
       ...,
       [ 33,  33,  33, ..., 199, 201, 201],
       [ 33,  33,  33, ..., 201, 205, 205],
       [ 33,  33,  33, ..., 201, 208, 204]], dtype=uint8)
```

```python
data.shape
```

executed in 8ms, finished 13:11:04 2022-05-01

```
(4240, 3480)
```

Vectorizing

Resizing (1000 x 1000)

Matrix to Vector

```
3 from skimage.transform import resize
```

```
1 vector_sample_lst = []
2 for i in range(len(img_sample_lst)):
3     raw_img = read_xray(img_sample_lst[i])
4     image = resize(raw_img, (1000, 1000), anti_aliasing=True)
5     vector_data = np.ravel(image)
6     vector_sample_lst.append(vector_data)
7 vector_sample_array = np.array(vector_sample_lst)
8 vector_sample_array.shape
9
```

executed in 21m 18s, finished 17:07:06 2022-04-30

```
(394, 1000000)
```

images (rows)

columns

Transform list into a numpy array

Saving the variables (Pickle file)

```
1 import pickle
2
```

execution queued 13:12:30 2022-05-01

```
1 with open('vector_train_lst.pkl', 'wb') as f:
2     pickle.dump(vector_train_lst, f)
```

execution queued 13:12:31 2022-05-01

Building Final Dataframe

```
image = img_sample_lst[1]
ds = pydicom.read_file(image)

```

executed in 36ms, finished 15:14:10 2022-04-30

```
ds
```

executed in 25ms, finished 15:14:13 2022-04-30

```
Dataset.file_meta -------------------------------
(0002, 0000) File Meta Information Group Length  UL: 244
(0002, 0001) File Meta Information Version       OB: b'\x00\x01'
(0002, 0002) Media Storage SOP Class UID         UI: Computed Radiography Image Storage
(0002, 0003) Media Storage SOP Instance UID      UI: 1.2.826.0.1.3680043.8.498.10242799675195671634897807131985
48
(0002, 0010) Transfer Syntax UID                 UI: JPEG 2000 Image Compression (Lossless Only)
(0002, 0012) Implementation Class UID            UI: 1.2.826.0.1.3680043.2.1143.107.104.103.115.3.0.10
(0002, 0013) Implementation Version Name         SH: 'GDCM 3.0.10'
(0002, 0016) Source Application Entity Title     AE: 'gdcmconv'
-------------------------------------------------
(0008, 0008) Image Type                          CS: ['ORIGINAL', 'PRIMARY']
(0008, 0012) Instance Creation Date              DA: ''
(0008, 0013) Instance Creation Time              TM: ''
(0008, 0016) SOP Class UID                       UI: Computed Radiography Image Storage
(0008, 0018) SOP Instance UID                    UI: 1.2.826.0.1.3680043.8.498.10242799675195671634897807131985000
48
(0008, 0020) Study Date                          DA: ''
(0008, 0021) Series Date                         DA: ''
(0008, 0023) Content Date                        DA: ''
(0008, 0030) Study Time                          TM: '111144'
(0008, 0033) Content Time                        TM: ''
(0008, 0050) Accession Number                    SH: '44'
(0008, 0060) Modality                            CS: 'CR'
(0008, 0070) Manufacturer                        LO: ''
(0008, 0090) Referring Physician's Name          PN: ''
(0008, 0100) Code Value                          SH: ''
(0008, 1030) Study Description                   LO: 'XRAY'
```

```
elem = ds[0x0008, 0x0018]
elem.value

```

executed in 14ms, finished 15:14:28 2022-04-30

```
'1.2.826.0.1.3680043.8.498.10242799675195671634897807131985000448'
```

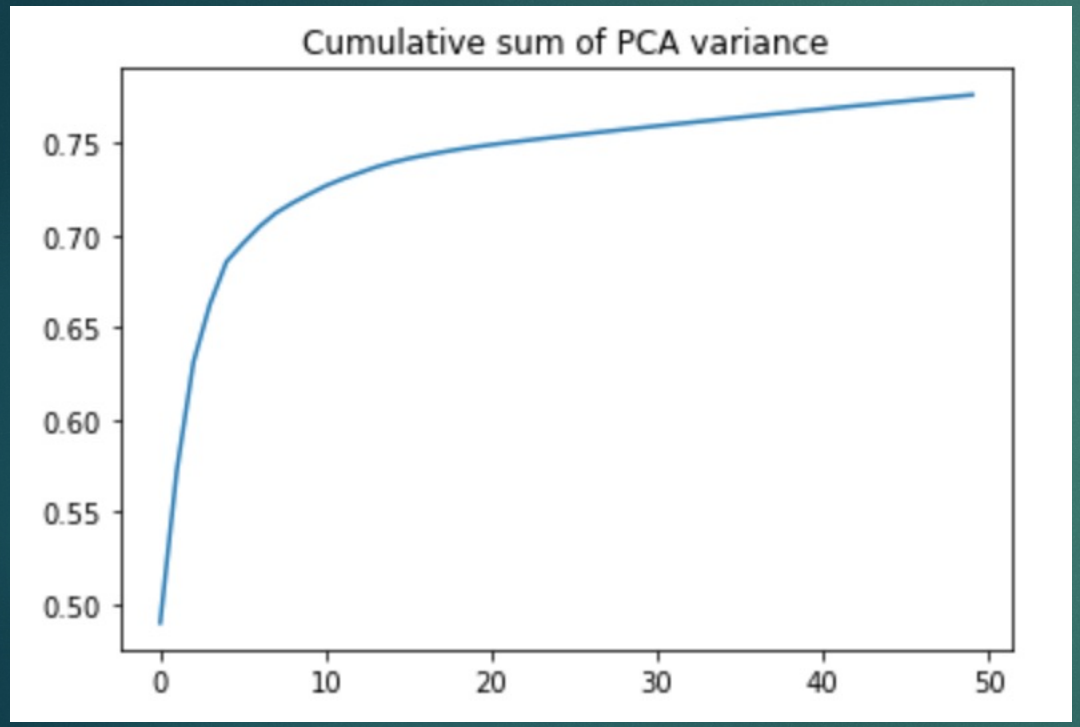
```
img_train_path_lst[10]
```

executed in 10ms, finished 13:07:51 2022-05-01

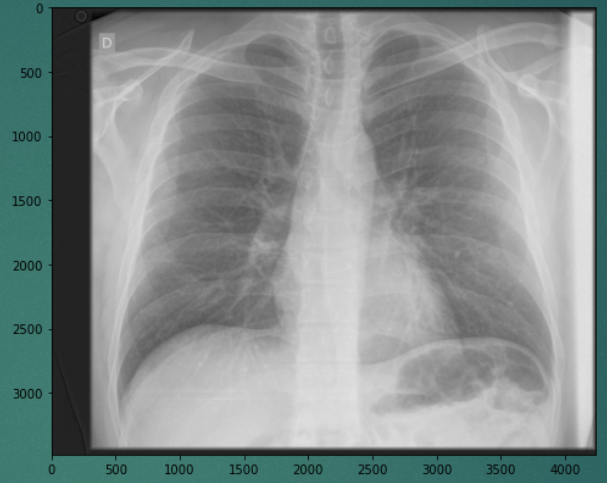
```
PosixPath('/Users/sgp/Documents/Ironhack/UNIFESP/data/train/train/551/1.2.826.0.1.3680043.8.498.1271226989
913451685597286950986823518 5/1.2.826.0.1.3680043.8.498.92431415960645296627687224582731905308/1.2.826.0.1.
3680043.8.498.95024973449301076445329863637538348478-c.dcm')
```

	SOPInstanceUID	Target	Path	Anatomy
0	1.2.826.0.1.3680043.8.498.10025629581362719970...	0	/Users/sgp/Documents/Ironhack/UNIFESP/data/tra...	Abdomen
1	1.2.826.0.1.3680043.8.498.10065930002825553435...	13	/Users/sgp/Documents/Ironhack/UNIFESP/data/tra...	Lumbar Spine
2	1.2.826.0.1.3680043.8.498.10107388868056003719...	0	/Users/sgp/Documents/Ironhack/UNIFESP/data/tra...	Abdomen
3	1.2.826.0.1.3680043.8.498.10166555243811009418...	21	/Users/sgp/Documents/Ironhack/UNIFESP/data/tra...	Wrist
4	1.2.826.0.1.3680043.8.498.10181745787571911943...	0	/Users/sgp/Documents/Ironhack/UNIFESP/data/tra...	Abdomen

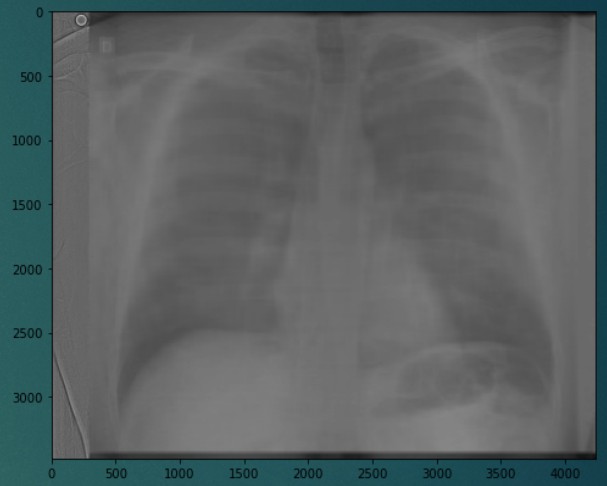
Principle Component Analysis (PCA)



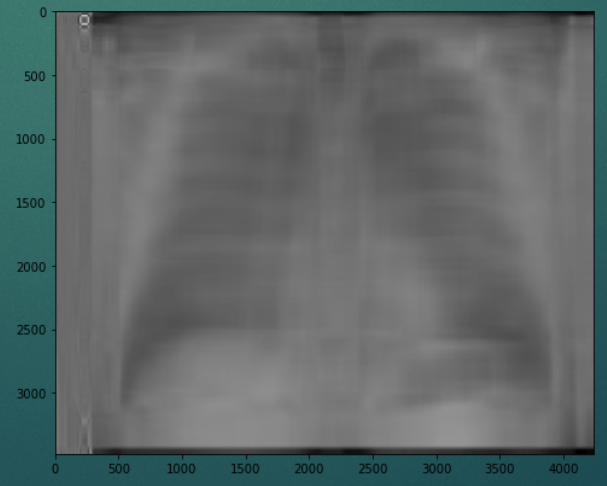
Original



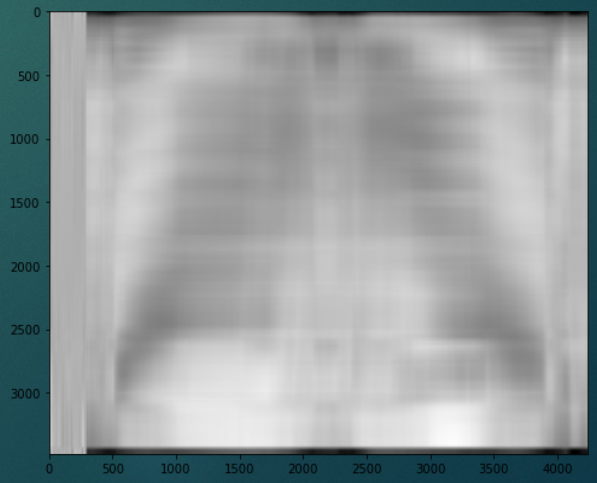
PCA 50



PCA 10



PCA 5



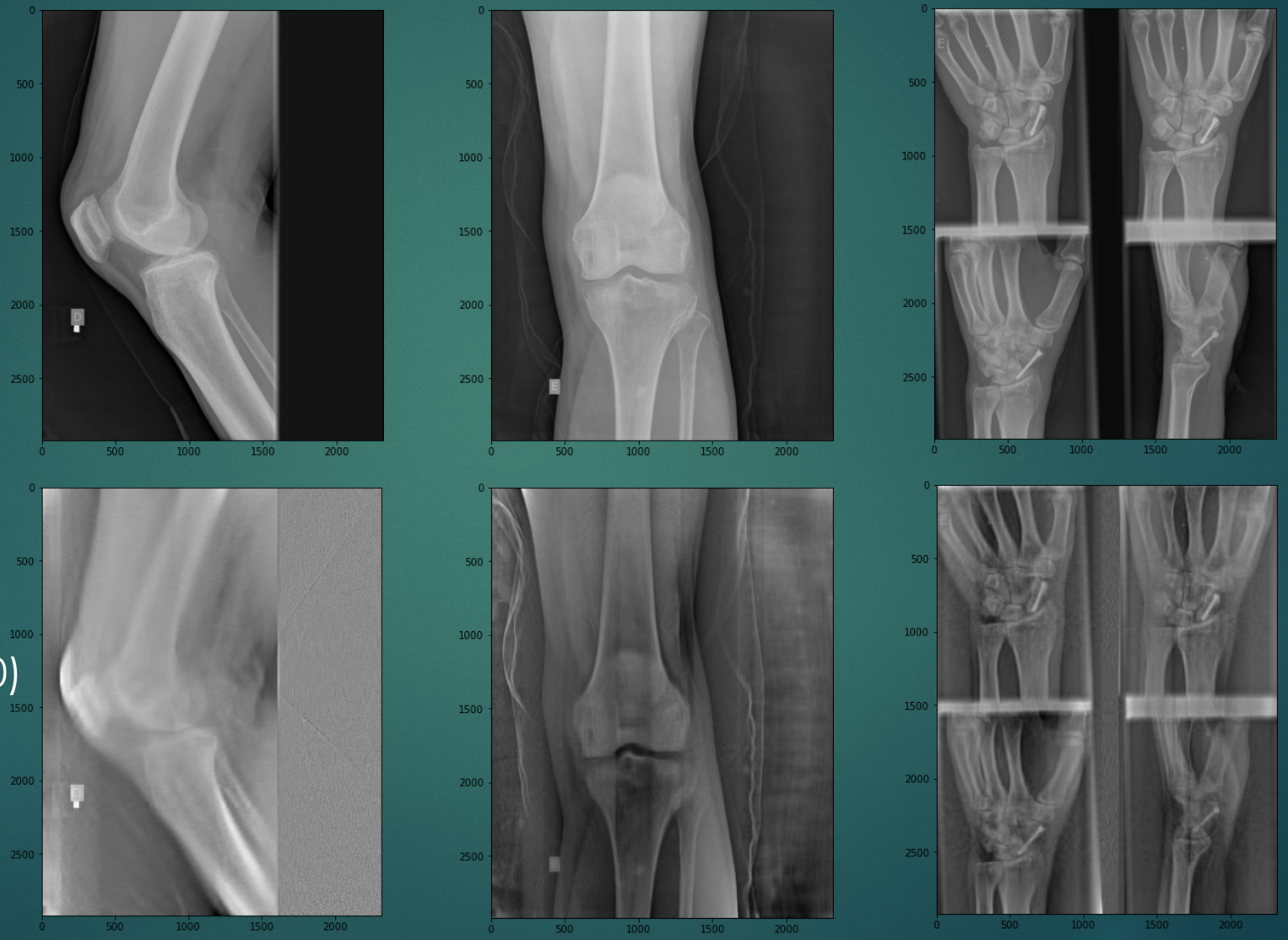
Principle Component Analysis (PCA)

Original images

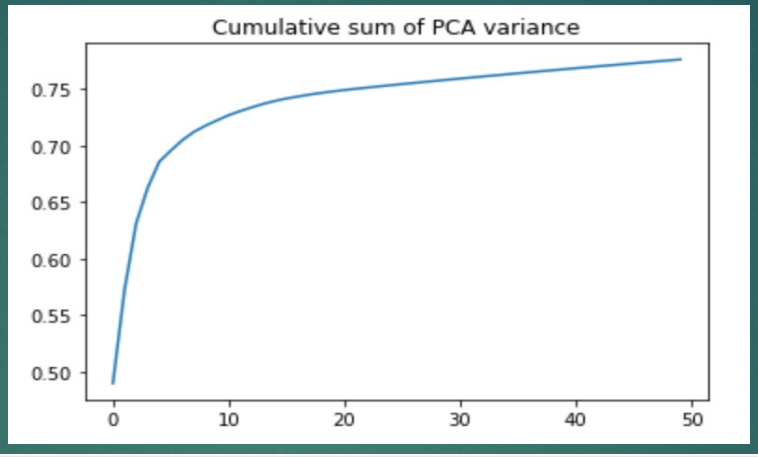
(2920 x 2320)

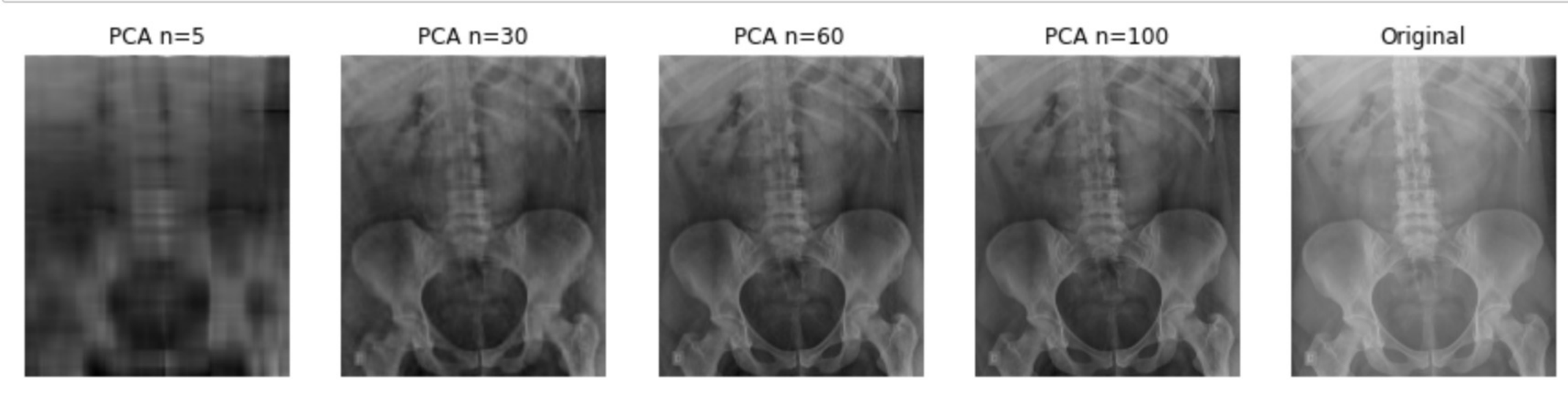
PCA (n_components=50)

(2920 x 50)



Principle Component Analysis (PCA)

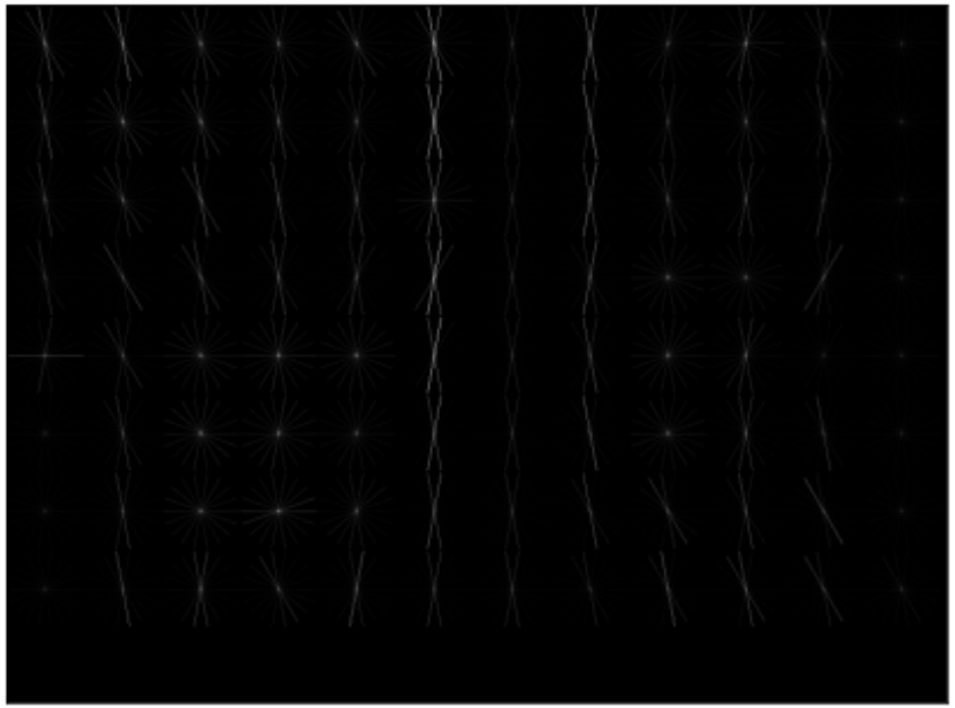




Histogram of Oriented Gradients (HOG)

Original

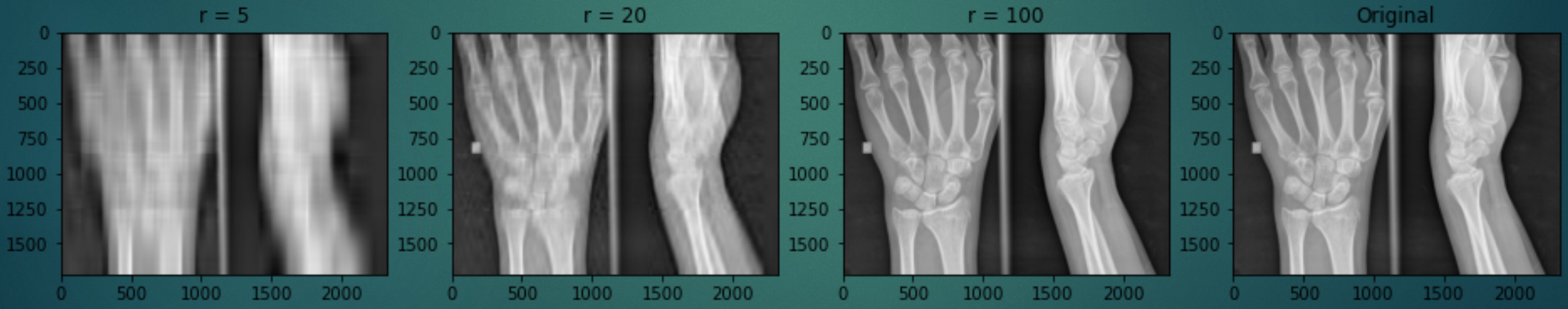
HOG



```
Number of pixels:  442929
Number of HOG features:  2772
np.mean(xray_hog_img): 0.0003925043990108372
```

Singular Value Decomposition (SVD)

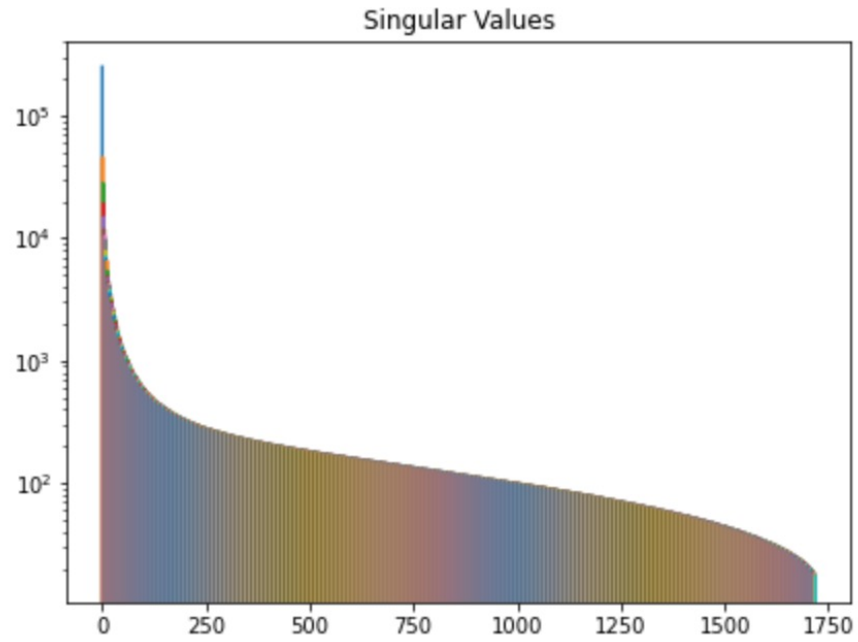
```
3 for r in (5, 20, 100):
4     Xapprox = u[:,:r] @ np.diag(s)[0:r, :r] @ v[:r,:]
```

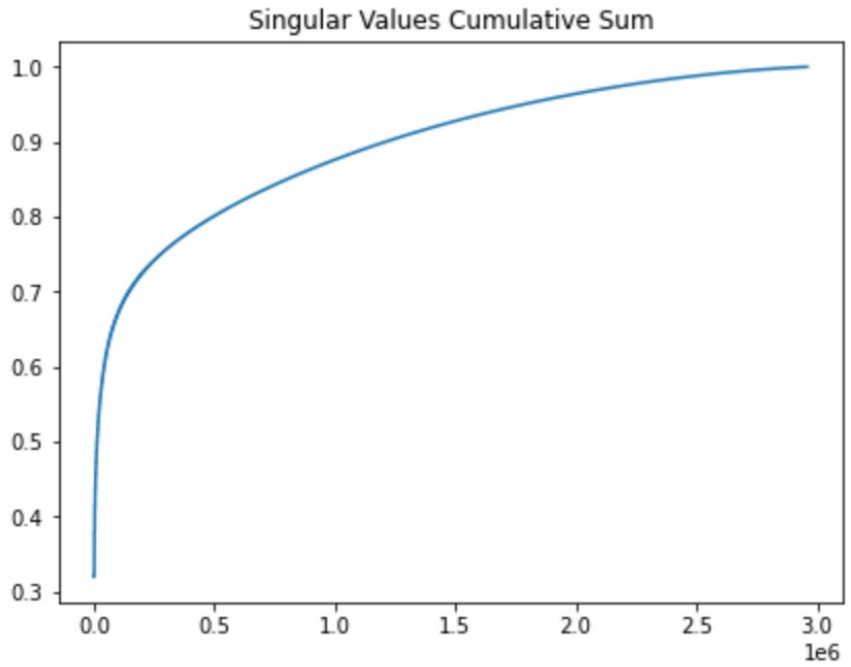


Singular Value Decomposition (SVD)

```
1 u, s, v = np.linalg.svd(data, full_matrices=False)
2 fig, ax = plt.subplots(1,2, figsize=(15,5))
3 ax[0].semilogy(np.diag(s));
4 ax[0].set_title('Singular Values')
5 ax[1].plot(np.cumsum(np.diag(s)/np.sum(np.diag(s))));
6 ax[1].set_title('Singular Values Cumulative Sum');
```

executed in 5.31s, finished 21:35:12 2022-05-02





Models (Classifiers)

- Stochastic Gradient Descent (SGD)

```
1 sgd_clf = SGDClassifier(random_state=42, max_iter=1000, tol=1e-3)
2 sgd_clf.fit(pca_data_train, y_train)
```

executed in 65ms, finished 22:38:30 2022-05-05

```
SGDClassifier(random_state=42)
```

- CatBoost

```
1 cat_fit = cat.CatBoostClassifier(
2     iterations=20000, depth=8, auto_class_weights="Balanced", od_type="Iter", od_wait=500)
3 cat_fit.fit(pca_data_train, y_train,
4             eval_set=(pca_data_test, y_test))
5
```

executed in 47.9s, finished 19:13:01 2022-05-02

Models

- Stochastic Gradient Descent (SGD)

Sample: 2 labels (knee and wrist)

```
1  sgdc_pred = sgd_clf.predict(pca_data_test)
2  print(f"F1-Score PCA{pca_data_test.shape[1]}: {f1_score(y_test, sgdc_pred, average='weighted')}")
3
```

executed in 12ms, finished 19:28:12 2022-05-02

```
F1-Score PCA50: 0.8129334965320277
```

Sample: 6 labels (knee, wrist, abdomen, l. spine, c. spine, feet)

```
1  sgdc_pred = sgd_clf.predict(pca_data_test)
2  print(f"F1-Score PCA{pca_data_test.shape[1]}: {f1_score(y_test, sgdc_pred, average='weighted')}")
3
```

executed in 15ms, finished 23:37:22 2022-05-02

```
F1-Score PCA50: 0.3555522420184074
```

Models

- CatBoost

Sample: 2 labels (knee and wrist)

```
1  cat_pred = cat_fit.predict(pca_data_test)
2  print(f"F1-Score PCA{pca_data_test.shape[1]}: {f1_score(y_test, cat_pred, average='weighted')}")
3
```

executed in 11ms, finished 19:17:43 2022-05-02

```
F1-Score PCA50: 0.8121334681496463
```

Sample: 6 labels (knee, wrist, abdomen, l. spine, c. spine, feet)

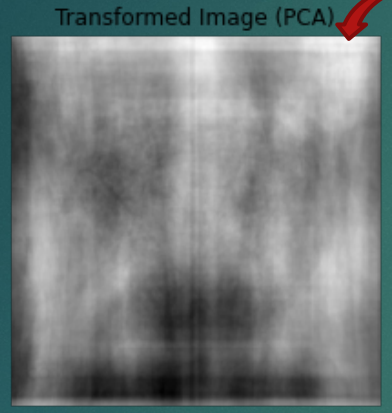
```
1  # 6 categories
2  cat_pred = cat_fit.predict(pca_data_test)
3  print(f"F1-Score PCA{pca_data_test.shape[1]}: {f1_score(y_test, cat_pred, average='weighted')}")
```

executed in 88ms, finished 00:08:25 2022-05-03

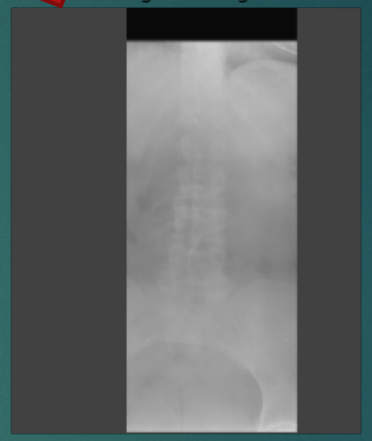
```
F1-Score PCA50: 0.7978020272243637
```

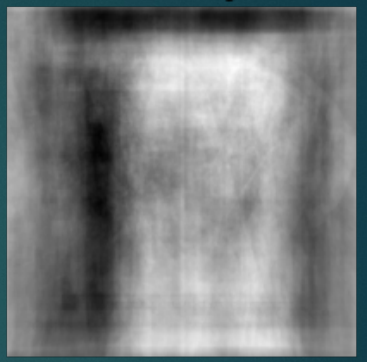
Visualizing the Results

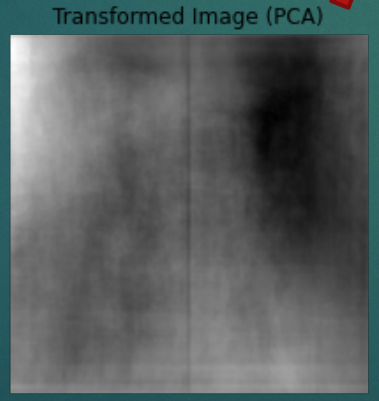
From the CatBoost Model (6 categories)
F1score = 0.79

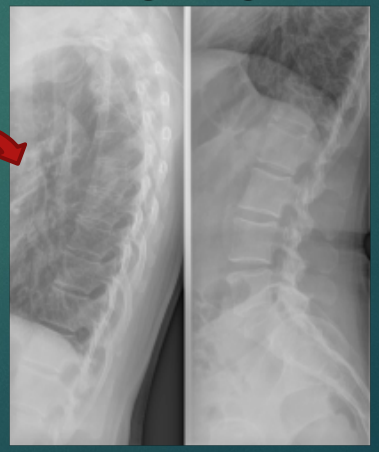


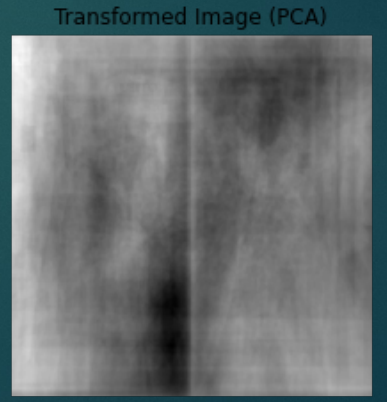
	index	Real_Anatomy	Pred_Anatomy
0	270	Lumbar Spine	Cervical Spine
1	90	Wrist	Wrist
2	133	Wrist	Wrist
3	221	Wrist	Wrist
4	224	Wrist	Knee
5	286	Abdomen	Abdomen
6	159	Lumbar Spine	Lumbar Spine
7	47	Lumbar Spine	Lumbar Spine
8	298	Abdomen	Abdomen
9	406	Cervical Spine	Cervical Spine
10	437	Wrist	Wrist
11	31	Wrist	Wrist
12	283	Lumbar Spine	Cervical Spine
13	267	Wrist	Wrist
14	326	Wrist	Wrist
15	334	Lumbar Spine	Lumbar Spine











Current State of the Project

- Dataframe:
  - Relevant information aggregated in one single table;
  - Image data aligned with dataframe values
- Images:
  - DICOM: loading and visualization
  - Resizing for standardization (1000 x 1000)
  - Conversion to a vector data (arrays)
  - Storage of image data (arrays) - Pickle
- Transformation/Compression algorithms:
  - PCA
  - HOG
  - SVD
- Classification Models:
  - CatBoost
  - SGD

Next Steps

- Look deeper into imaging standardization:
  - Resizing
  - File conversion
  - Contrast
- Test different transformation/compression algorithms and optimize parameters
- Classification models:
  - Parameters optimization
  - Test New models
- Work on a pipeline to automation of the entire process