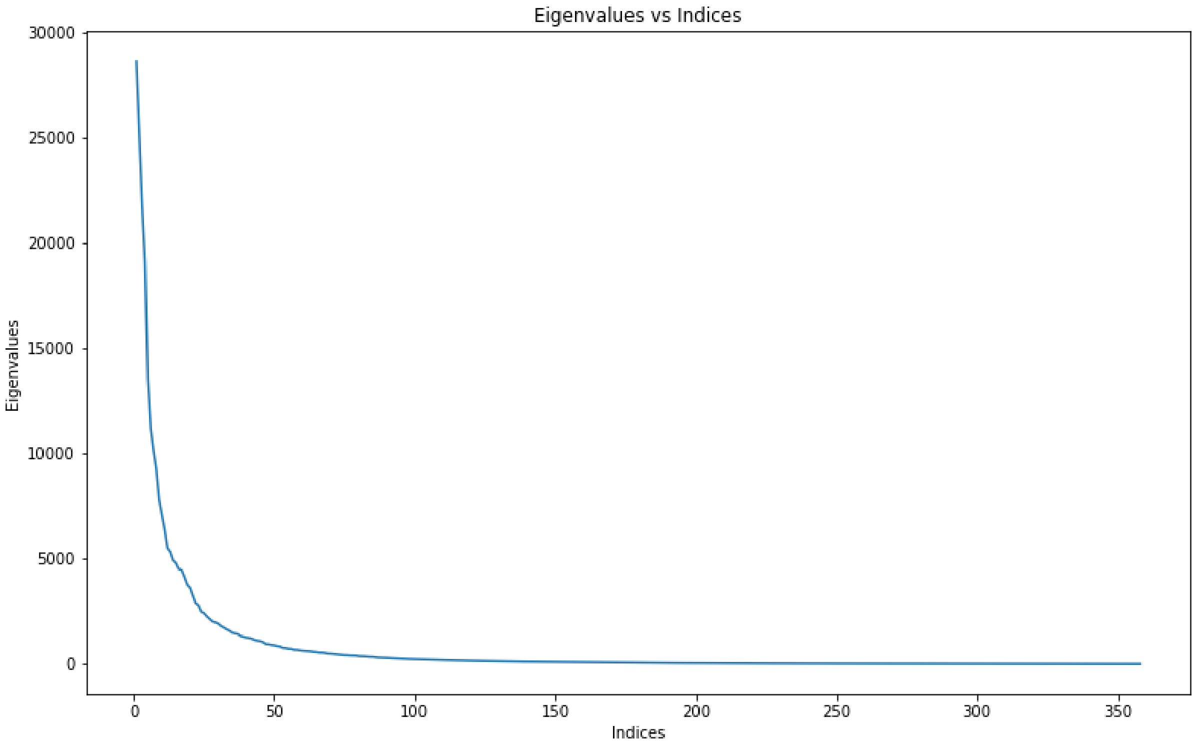
Jarod Klion

Homework 11

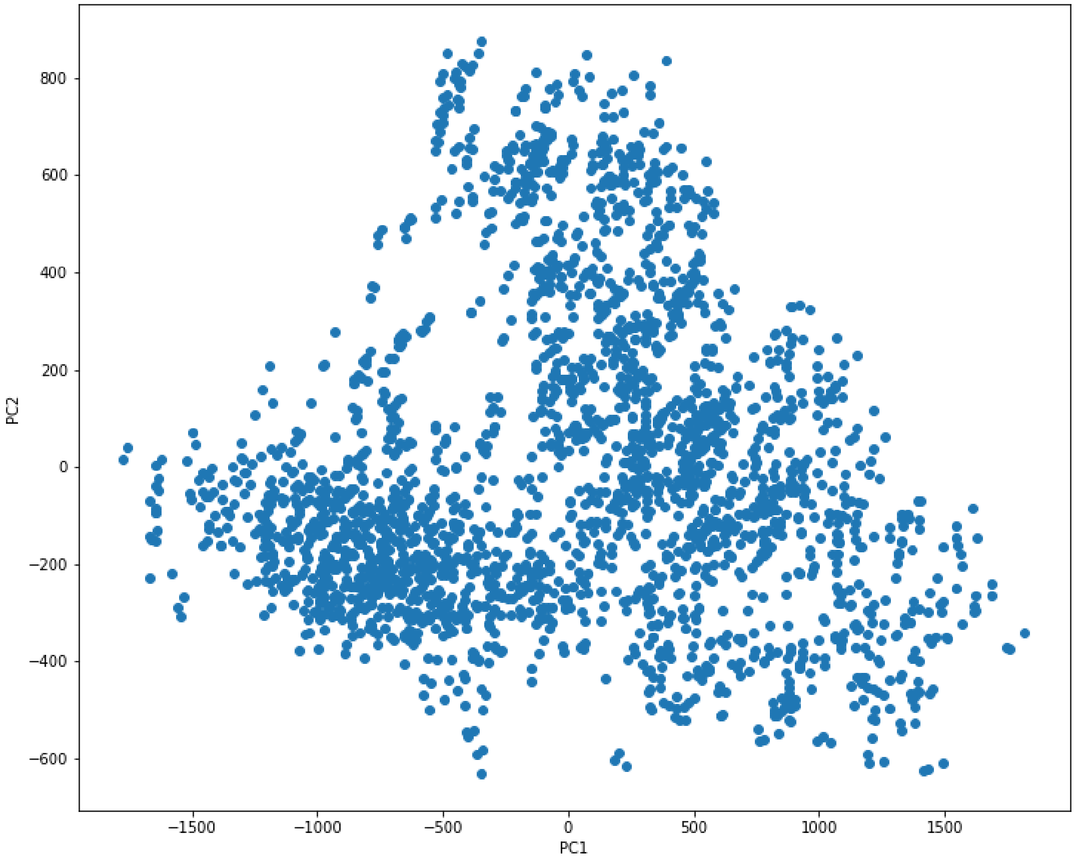
STA5635

April 5, 2022

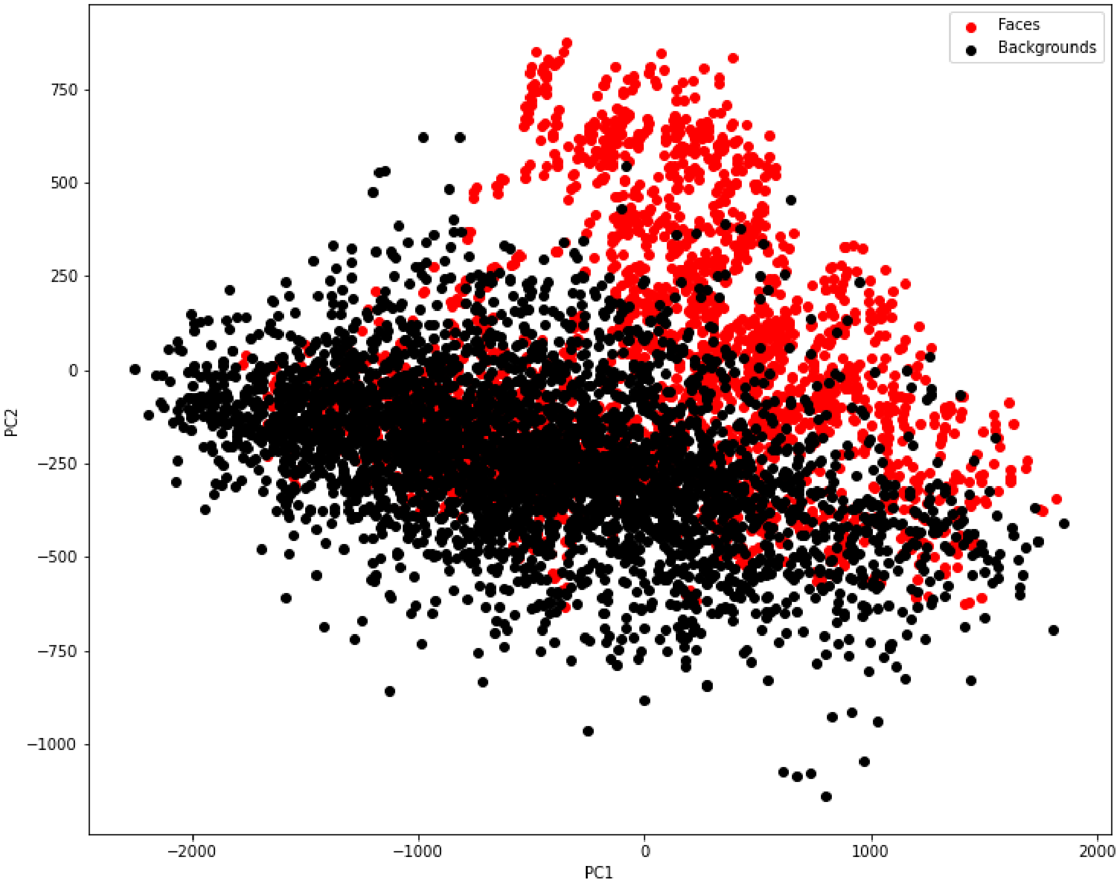
a. eigenvalues sorted in decreasing order



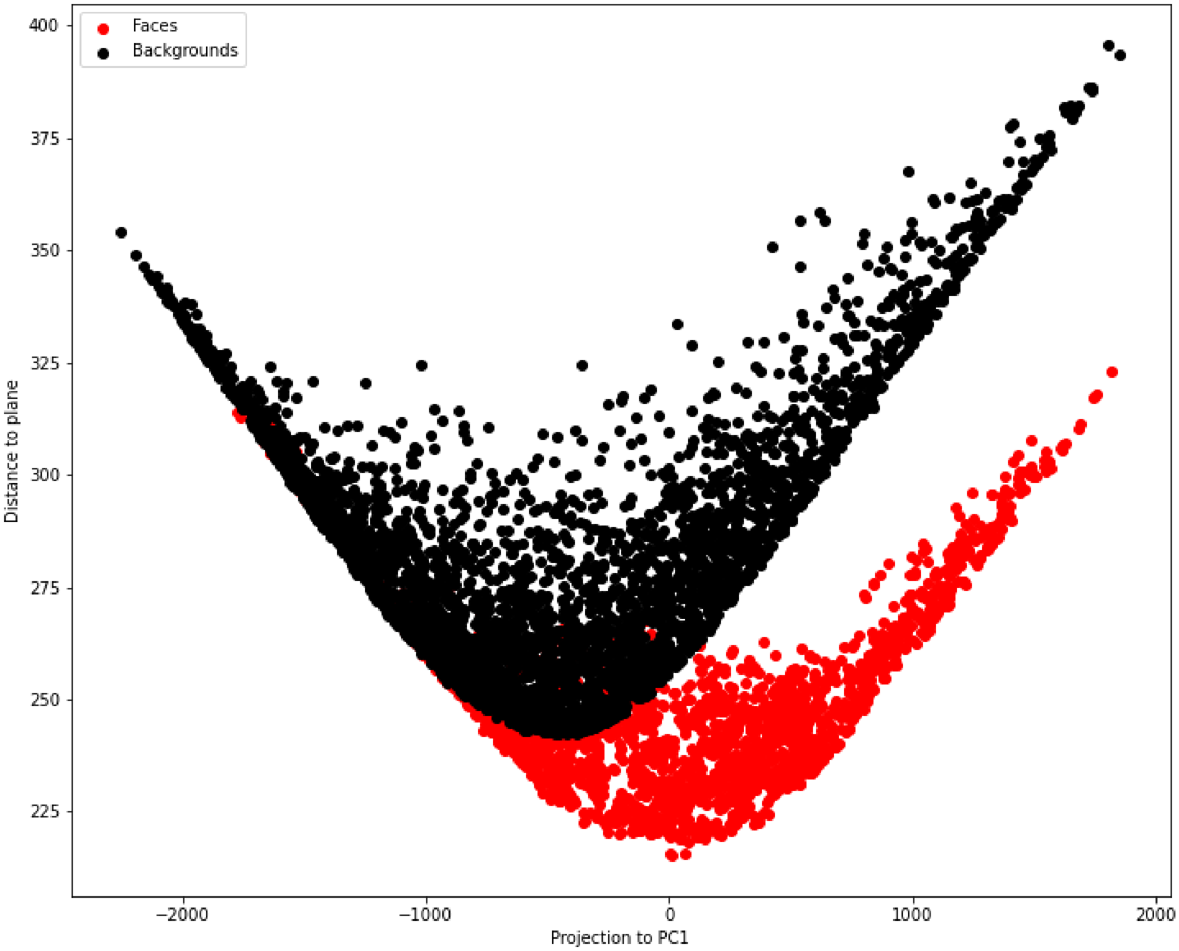
b. Coordinates of the faces projected to the 2D plane generated by PC1 and PC2



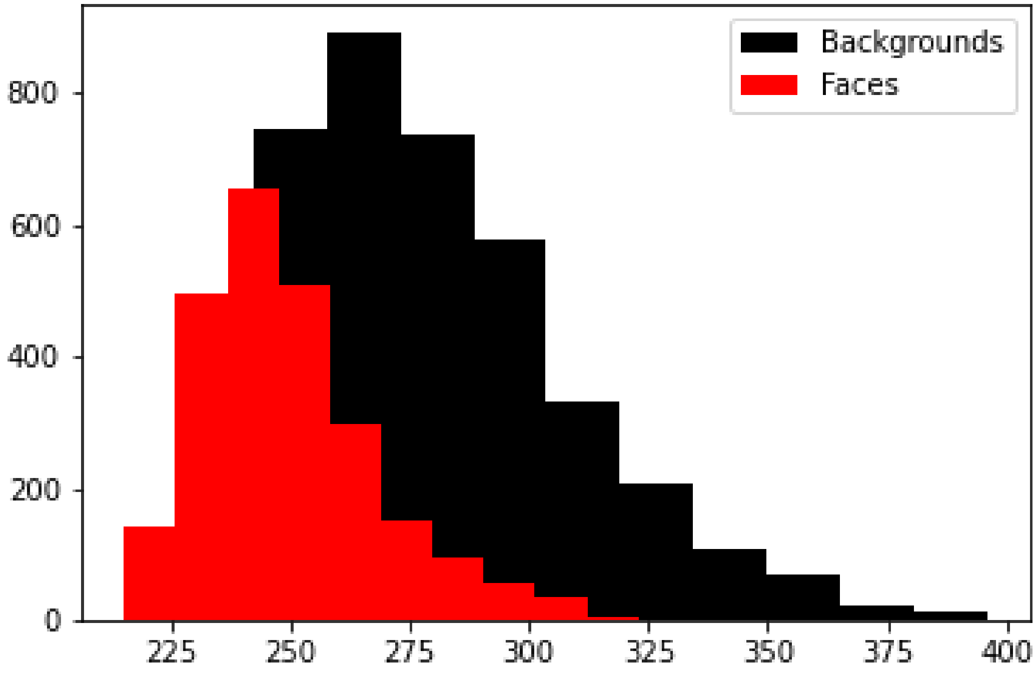
c. Coordinates of faces and backgrounds projected to 2D plane generated by PC1 and PC2



d. Distances to 15-PC plane vs projections of faces and backgrounds on the first PC



e. Histogram of distances from above



```
#!/usr/bin/env python
# coding: utf-8

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from sklearn.decomposition import PCA
import os




#read face images into a dict
faces = {}
for filename in os.listdir('../datasets/faces/'):
    if not filename.startswith('face0'):
        continue #not a faces pic
    faces[filename] = plt.imread(os.path.join('../datasets/faces',filename))




#look at a subset of images
fig, axes = plt.subplots(4, 4, sharex = True, sharey = True, figsize = (10,12))
faceimages = list(faces.values())[:16]
for i in range(16):
    axes[i % 4][i // 4].imshow(faceimages[i], cmap = 'gray')
plt.show()

faceshape = list(faces.values())[0].shape
print("Face image shape:", faceshape)




#create matrix to perform PCA
facematrix = []
for key, val in faces.items():
    facematrix.append(val.flatten())

#(n_samples, n_pixels) matrix -> (2429, 19x19)
facematrix = np.array(facematrix)
facematrix_centered = facematrix - np.mean(facematrix, axis = 0)
print(facematrix.shape)


# # Part A

pca = PCA().fit(facematrix_centered)


#print/store eigenvectors
#print(pca.components_)
eigenvectors = pca.components_[3:]
#print/store eigenvalues
eigenvalues = pca.explained_variance_[3:]
#make eigenvalue indices to plot against
eigenvalues_idx = range(1, len(eigenvalues) + 1)
```

```
#plot eigenvalues
plt.figure(figsize = (13, 8))
plt.plot(eigenvalues_idx, eigenvalues)
plt.xlabel("Indices")
plt.ylabel("Eigenvalues")
plt.title("Eigenvalues vs Indices")
plt.savefig("Eigenvalues.png")
plt.show()


# # Part B

two_pcas = PCA(n_components=2).fit(facematrix_centered)
faces_two = two_pcas.transform(facematrix_centered)


#plot projection onto PC1 and PC2
plt.figure(figsize = (12, 10))
plt.scatter(faces_two[:,0], faces_two[:,1])
plt.xlabel("PC1")
plt.ylabel("PC2")
plt.savefig("Faces Projection.png")
plt.show()

# # Part C

bgs = {}
for filename in os.listdir('../datasets/faces/'):
    if not filename.startswith('B'):
        continue #not a background pic
    bgs[filename] = plt.imread(os.path.join('../datasets/faces',filename))

fig, axes = plt.subplots(4, 4, sharex = True, sharey = True, figsize = (10,12))
bgimages = list(bgs.values())[:16]
for i in range(16):
    axes[i % 4][i // 4].imshow(bgimages[i], cmap = 'gray')
plt.show()

bgshape = list(bgs.values())[0].shape
print("Background image shape:", bgshape)



#create matrix
bgmatrix = []
bglabel = []
for key, val in bgs.items():
    bgmatrix.append(val.flatten())
    bglabel.append(key.split("_")[0])

#(n_samples, n_pixels) matrix -> (3699, 19x19)
bgmatrix = np.array(bgmatrix)
bgmatrix_centered = bgmatrix - np.mean(facematrix, axis = 0)
print(bgmatrix_centered.shape)
```

```
bgs_two = two_pcas.transform(bgmatrix_centered)


plt.figure(figsize = (12, 10))
plt.scatter(faces_two[:,0], faces_two[:,1], color = "red", label = "Faces")
plt.scatter(bgs_two[:,0], bgs_two[:,1], color = "black", label = "Backgrounds")
plt.xlabel("PC1")
plt.ylabel("PC2")
plt.legend()
plt.savefig("Faces and Backgrounds Projections.png")
plt.show()

# # Part D

fifteen_pca_components = pca.components_[:15]
first_comp = PCA(n_components=1).fit(facematrix_centered)
faces_one = first_comp.transform(facematrix_centered)
bgs_one = first_comp.transform(bgmatrix_centered)


#project of coordinates to PC plane
faceweights = fifteen_pca_components @ (facematrix_centered).T
bgweights = fifteen_pca_components @ (bgmatrix_centered).T

#create list for later storage
facedists = []
bgdists = []

for i in range(facematrix_centered.shape[0]):
    query_weight = fifteen_pca_components @ facematrix_centered[i, :,
np.newaxis]
    facedists.append(np.sqrt(np.linalg.norm(faceweights - query_weight)))

for i in range(bgmatrix_centered.shape[0]):
    query_weight = fifteen_pca_components @ bgmatrix_centered[i, :, np.newaxis]
    bgdists.append(np.sqrt(np.linalg.norm(bgweights - query_weight)))



plt.figure(figsize = (12, 10))
plt.scatter(faces_one, facedists, color = "red", label = "Faces")
plt.scatter(bgs_one, bgdists, color = "black", label = "Backgrounds")
plt.xlabel("Projection to PC1")
plt.ylabel("Distance to plane")
plt.legend()
plt.savefig("Distances vs Projection.png")
plt.show()


# # Part E

#plot histogram of distances
plt.hist(bgdists, color = 'black', label = 'Backgrounds')
plt.hist(facedists, color = 'red', label = 'Faces')
plt.legend()
plt.savefig("Histogram.png")
plt.show()
```