Import the data

In [ ]:

```
from IPython.display import Markdown as md
from sklearn.datasets import fetch_lfw_people
import matplotlib.pyplot as plt
import matplotlib.cm as cm
import pandas as pd
import numpy as np
from sklearn.neighbors import KNeighborsClassifier
from sklearn.model_selection import train_test_split as tts
```

In [ ]:

```
people = fetch_lfw_people(min_faces_per_person=20, resize=0.7)
image_shape = people.images[0].shape

fig, axes = plt.subplots(2, 5, figsize=(15, 8),
                         subplot_kw={'xticks': (), 'yticks': ()})
for target, image, ax in zip(people.target, people.images, axes.ravel()):
    ax.imshow(image, cmap=cm.gray)
    ax.set_title(people.target_names[target], color='red')
```

Section 2 -- Dimensionality Reduction via PCA

In [ ]:

```
print(f"{people.images.shape=}")
print(f"Number of classes: {len(people.target_names)}\n")

counts = np.bincount(people.target)
for i, (count, name) in enumerate(zip(counts, people.target_names)):
    print("{0:25} {1:3}".format(name, count), end='   ')
    if (i + 1) % 3 == 0:
        print()

mask = np.zeros(people.target.shape, dtype=bool)
for target in np.unique(people.target):
    mask[np.where(people.target == target)[0][:50]] = 1

X_people = people.data[mask]
y_people = people.target[mask]
X_people = X_people / 255

trainX, testX, trainY, testY = tts(X_people, y_people, stratify=y_people, random_state=0)
knn = KNeighborsClassifier(n_neighbors=1)
knn.fit(trainX, trainY)

md(f"Test set score of 1-nn: $${knn.score(testX, testY)*100:.4f}\%$$")
```

```
people.images.shape=(3023, 87, 65)
Number of classes: 62

Alejandro Toledo           39   Alvaro Uribe               35   Amelie Mauresmo            21
Andre Agassi               36   Angelina Jolie             20   Ariel Sharon               77
Arnold Schwarzenegger      42   Atal Bihari Vajpayee       24   Bill Clinton               29
Carlos Menem               21   Colin Powell              236   David Beckham              31
Donald Rumsfeld           121   George Robertson           22   George W Bush             530
Gerhard Schroeder         109   Gloria Macapagal Arroyo    44   Gray Davis                 26
Guillermo Coria            30   Hamid Karzai               22   Hans Blix                  39
Hugo Chavez                71   Igor Ivanov                20   Jack Straw                 28
Jacques Chirac             52   Jean Chretien              55   Jennifer Aniston           21
Jennifer Capriati          42   Jennifer Lopez             21   Jeremy Greenstock          24
Jiang Zemin                20   John Ashcroft              53   John Negroponte            31
Jose Maria Aznar           23   Juan Carlos Ferrero        28   Junichiro Koizumi          60
Kofi Annan                 32   Laura Bush                 41   Lindsay Davenport          22
Lleyton Hewitt             41   Luiz Inacio Lula da Silva  48   Mahmoud Abbas              29
Megawati Sukarnoputri      33   Michael Bloomberg          20   Naomi Watts                22
Nestor Kirchner            37   Paul Bremer                20   Pete Sampras               22
Recep Tayyip Erdogan       30   Ricardo Lagos              27   Roh Moo-hyun               32
Rudolph Giuliani           26   Saddam Hussein             23   Serena Williams            52
Silvio Berlusconi          33   Tiger Woods                23   Tom Daschle                25
Tom Ridge                  33   Tony Blair                144   Vicente Fox                32
Vladimir Putin             49   Winona Ryder               24
```

Out[ ]: Test set score of 1-nn:

$$23.2558\%$$

Create KNN functions

In [ ]:

```python
def SSD(trainX, testX):
    return ((trainX - testX) ** 2).sum(axis=1)

def KNN(trainX, testX, trainY):
    return np.take(trainY, SSD(trainX, testX).argmin())

def prediction(trainX, testX, trainY):
    return [KNN(trainX, test, trainY) for test in testX]

def accuracy(yhat, y):
    accuracy = np.where(yhat == y, 1, 0).mean() * 100
    return md(f'$$ Accuracy: {accuracy:.4f}\% $$')

accuracy(yhat=prediction(trainX, testX, trainY), y=testY)
```

Out[ ]:

$$Accuracy: 23.2558\%$$

In [ ]:

```
mean = trainX.mean(axis=0)
std = trainX.std(axis=0, ddof=1)
####################################################################
trainX_std = (trainX - mean) / std
testX_std = (testX - mean) / std
####################################################################

_ , s, vT = np.linalg.svd(trainX_std)
eigen_val = s**2 / (trainX_std.shape[0] - 1)
eigen_vec = vT.T

####################################################################

indices = np.arange(100)
dim_100_eigen_val = np.take(eigen_val, indices)
dim_100_eigen_vec = np.take(eigen_vec, indices, axis=1)
trainProj = trainX_std @ dim_100_eigen_vec
testProj = testX_std @ dim_100_eigen_vec

####################################################################

accuracy(yhat=prediction(trainProj, testProj, trainY), y=testY)
```

Out[ ]:

$$Accuracy : 25.3876\%$$

In [ ]:

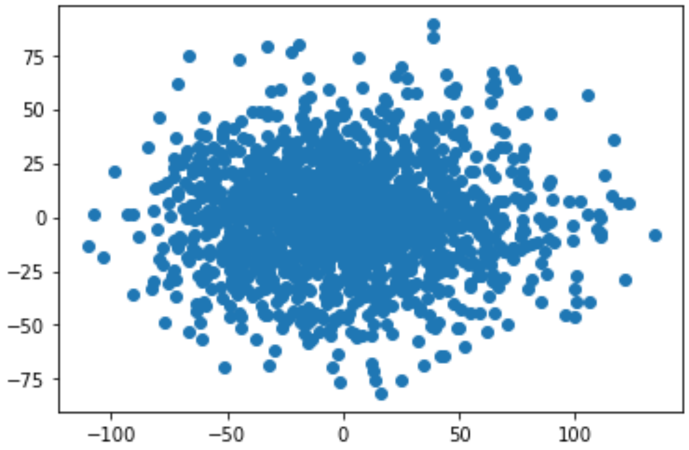
```
topValuesDiag = np.diag(dim_100_eigen_val ** (-1/2))
trainWhitened = (topValuesDiag @ dim_100_eigen_vec.T @ trainX_std.T).T
testWhitened = (topValuesDiag @ dim_100_eigen_vec.T @ testX_std.T).T

accuracy(yhat=prediction(trainWhitened, testWhitened, trainY), y=testY)
```

Out[ ]:

$$Accuracy : 33.1395\%$$

In [ ]:

```
indices = np.arange(2)
best_two_eigen_vec = np.take(eigen_vec, indices, axis=1)
trainProj = trainX_std @ best_two_eigen_vec
plt.scatter(trainProj[:,0], trainProj[:,1])
plt.show()
```



Section 3 -- Eigenfaces

In [ ]:

```
import matplotlib.cm as cm
import matplotlib.pyplot as plt
import numpy as np
from IPython.display import Markdown as md
from sklearn.datasets import fetch_lfw_people
from sklearn.model_selection import train_test_split as tts
from sklearn.neighbors import KNeighborsClassifier

people = fetch_lfw_people(min_faces_per_person=20, resize=0.7)
image_shape = people.images[0].shape

fig, axes = plt.subplots(2, 5, figsize=(15, 8),
                         subplot_kw={'xticks': (), 'yticks': ()})
for target, image, ax in zip(people.target, people.images, axes.ravel()):
    ax.imshow(image, cmap=cm.gray)
    ax.set_title(people.target_names[target], color='red')

print(f"{people.images.shape=}")
print(f"Number of classes: {len(people.target_names)}\n")

counts = np.bincount(people.target)
for i, (count, name) in enumerate(zip(counts, people.target_names)):
    print("{0:25} {1:3}".format(name, count), end='   ')
    if (i + 1) % 3 == 0:
        print()

mask = np.zeros(people.target.shape, dtype=bool)
for target in np.unique(people.target):
    mask[np.where(people.target == target)[0][:50]] = 1

X_people = people.data[mask]
y_people = people.target[mask]
X_people = X_people / 255

trainX, testX, trainY, testY = tts(X_people, y_people, stratify=y_people, random_state=0)

mean = trainX.mean(axis=0)
std = trainX.std(axis=0, ddof=1)
####################################################################
trainX_std = (trainX - mean) / std
testX_std = (testX - mean) / std
####################################################################

_ , s, vT = np.linalg.svd(trainX_std)
eigen_val = s**2 / (trainX_std.shape[0] - 1)
eigen_vec = vT.T
```

```
indices = np.arange(2)
best_two_eigen_vec = np.take(eigen_vec, indices, axis=1)
trainProj = trainX_std @ best_two_eigen_vec
```

```
people.images.shape=(3023, 87, 65)
Number of classes: 62

Alejandro Toledo           39   Alvaro Uribe               35   Amelie Mauresmo            21
Andre Agassi               36   Angelina Jolie             20   Ariel Sharon               77
Arnold Schwarzenegger      42   Atal Bihari Vajpayee       24   Bill Clinton               29
Carlos Menem               21   Colin Powell              236   David Beckham              31
Donald Rumsfeld           121   George Robertson           22   George W Bush             530
Gerhard Schroeder         109   Gloria Macapagal Arroyo    44   Gray Davis                 26
Guillermo Coria            30   Hamid Karzai               22   Hans Blix                  39
Hugo Chavez                71   Igor Ivanov                20   Jack Straw                 28
Jacques Chirac             52   Jean Chretien              55   Jennifer Aniston           21
Jennifer Capriati          42   Jennifer Lopez             21   Jeremy Greenstock          24
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Kofi Annan                 32   Laura Bush                 41   Lindsay Davenport          22
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Megawati Sukarnoputri      33   Michael Bloomberg          20   Naomi Watts                22
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Recep Tayyip Erdogan       30   Ricardo Lagos              27   Roh Moo-hyun               32
Rudolph Giuliani           26   Saddam Hussein             23   Serena Williams            52
Silvio Berlusconi          33   Tiger Woods                23   Tom Daschle                25
Tom Ridge                  33   Tony Blair                144   Vicente Fox                32
Vladimir Putin             49   Winona Ryder               24
```
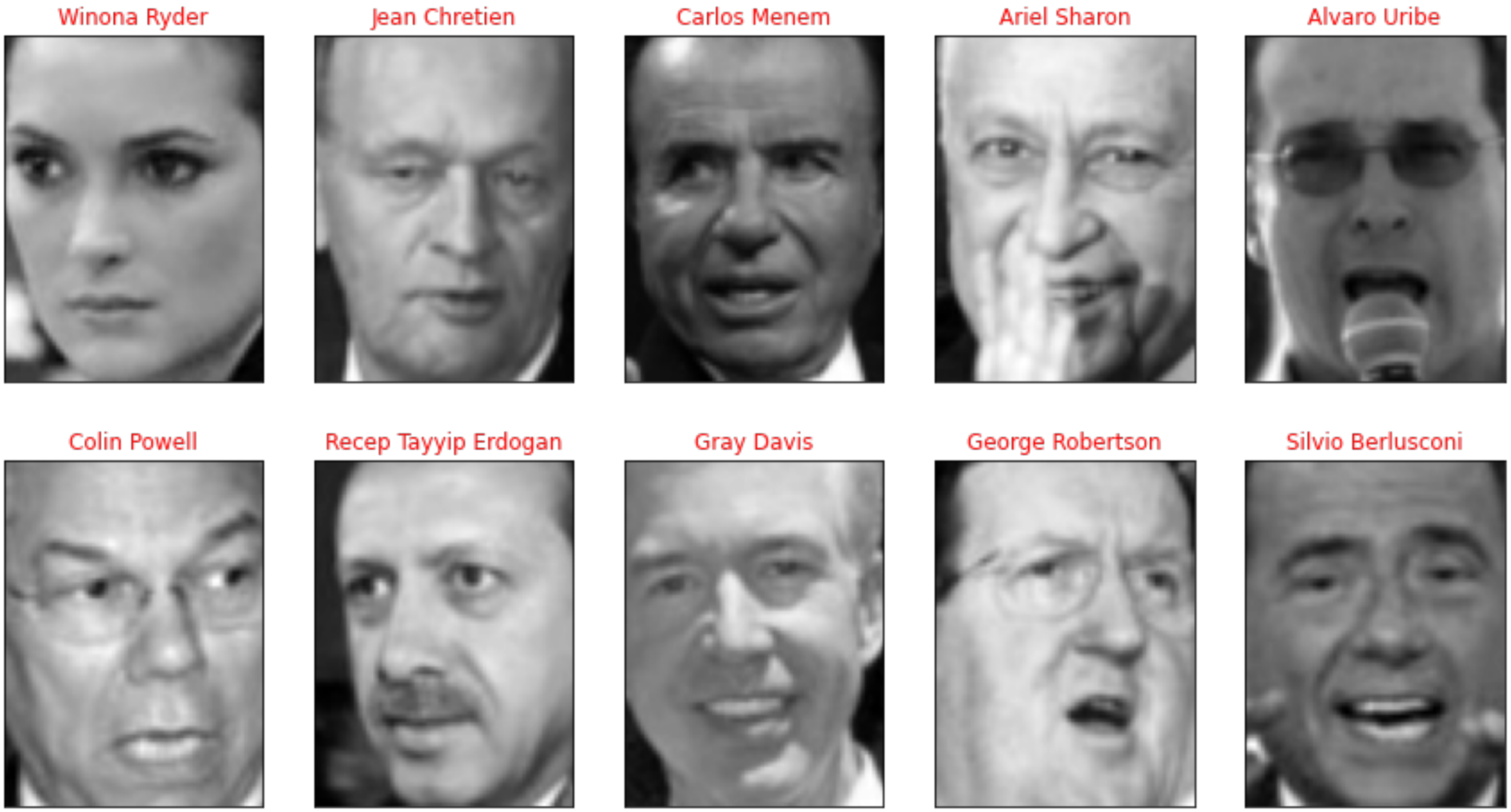


Winona Ryder
Jean Chretien
Carlos Menem
Ariel Sharon
Alvaro Uribe
Colin Powell
Recep Tayyip Erdogan
Gray Davis
George Robertson
Silvio Berlusconi

In [ ]:

```
PC1 = np.take(trainProj, 0, axis=1)
PC2 = np.take(trainProj, 1, axis=1)

PC1_min_idx = PC1.argmin()
PC1_max_idx = PC1.argmax()
PC2_min_idx = PC2.argmin()
PC2_max_idx = PC2.argmax()



images = [np.take(trainX_std, PC1_min_idx, axis=0).reshape(87, 65),
    np.take(trainX_std, PC1_max_idx, axis=0).reshape(87, 65),
    np.take(trainX_std, PC2_min_idx, axis=0).reshape(87, 65),
    np.take(trainX_std, PC2_max_idx, axis=0).reshape(87, 65),
]


targets = [people.target_names[np.take(trainY, PC1_min_idx, axis=0)],
    people.target_names[np.take(trainY, PC1_max_idx, axis=0)],
    people.target_names[np.take(trainY, PC2_min_idx, axis=0)],
    people.target_names[np.take(trainY, PC2_max_idx, axis=0)],
]

fig, axes = plt.subplots(2, 2, figsize=(15, 8),
                         subplot_kw={'xticks': (), 'yticks': ()})

for target, image, ax in zip(targets, images, axes.ravel()):
    ax.imshow(image, cmap=cm.gray)
    ax.set_title(target, color='red')
```

George Robertson

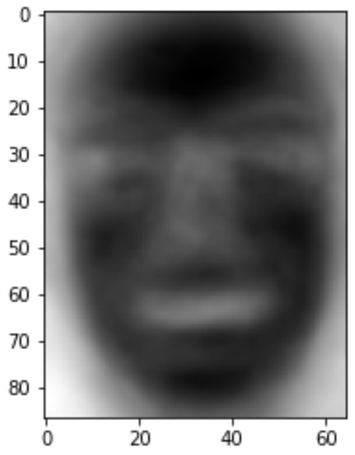
Kofi Annan

George W Bush

Guillermo Coria

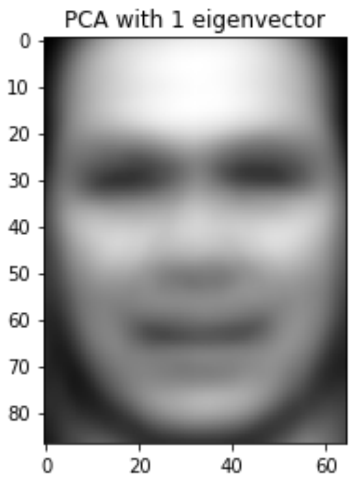
In [ ]:

```
plt.imshow(best_two_eigen_vec[:,0].reshape(87,65), cmap=cm.gray)
plt.show()
```



In [ ]:

```
indices = [1]
reconstructionVec = np.take(eigen_vec, indices, axis=1)
reconstructedImg = trainX[0] @ reconstructionVec @ reconstructionVec.T
reconstructedImg = reconstructedImg * std + mean
plt.imshow(reconstructedImg.reshape(87, 65), cmap=cm.gray)
plt.title('PCA with 1 eigenvector')
plt.show()
```



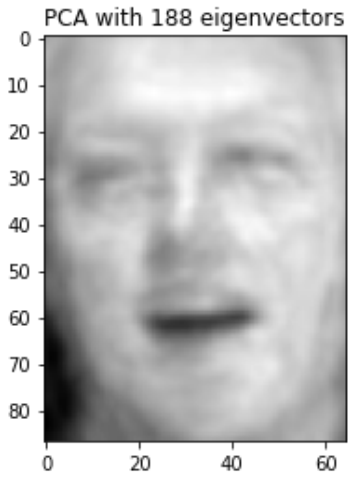
In [ ]:

```
k = 0
cumsum = np.cumsum(eigen_val)
total = cumsum[-1]
while (cumsum[k] / total <= .95):
    k += 1
print(f"Num of eigenvectors needed: {k}")
```

```
Num of eigenvectors needed: 188
```

In [ ]:

```
indices = np.arange(k)
reconstructionVec95 = eigen_vec[:,indices]
reconstructedImg95 = trainX[0] @ reconstructionVec95 @ reconstructionVec95.T
plt.imshow(reconstructedImg95.reshape(87, 65), cmap=cm.gray)
plt.title(f'PCA with {k} eigenvectors')
plt.show()
```


PCA with 188 eigenvectors