Instructions

Follow the instructions given in comments prefixed with ## and write your code below that.

Also fill the partial code in given blanks.

Don't make any changes to the rest part of the codes

Answer the questions given at the end of this notebook within your report.

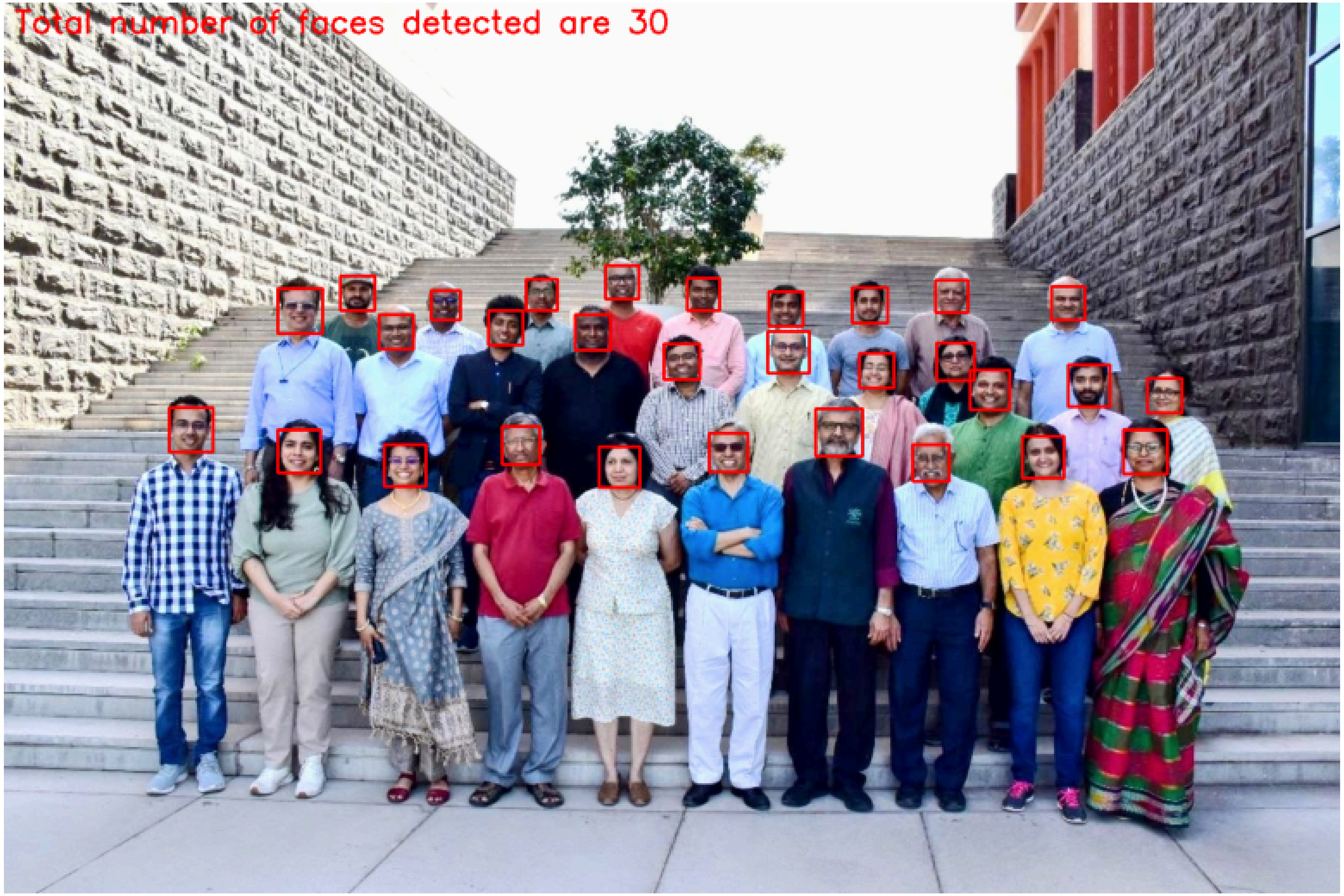
You would need to submit your GitHub repository link. Refer to the PDF document for the instructions and details.

In [1]:
```
import cv2
import numpy as np
import matplotlib.pyplot as plt
from sklearn.cluster import KMeans
import scipy.spatial.distance
from matplotlib.offsetbox import OffsetImage, AnnotationBbox
```

In [2]:
```
## Reading the image plaksha_Faculty.jpg
img = cv2.imread('Plaksha_Faculty.jpg')

## Convert the image to grayscale
gray_img = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

# Loading the required haar-cascade xml classifier file
face_cascade = cv2.CascadeClassifier(cv2.data.haarcascades + 'haarcascade_frontalface_default.xml')

# Applying the face detection method on the grayscale image.
## Change the parameters for better detection of faces in your case.
faces_rect = face_cascade.detectMultiScale(gray_img, 1.05, 4, minSize=(25,25), maxSize=(50,50))

# Define the text and font parameters
text = f"Total number of faces detected are {len(faces_rect)}" ## The text you want to write
font = cv2.FONT_HERSHEY_SIMPLEX  ## Font type
font_scale = 1  ## Font scale factor
font_color = (0, 0, 255)  ## Text color in BGR format (here, it's red)
```

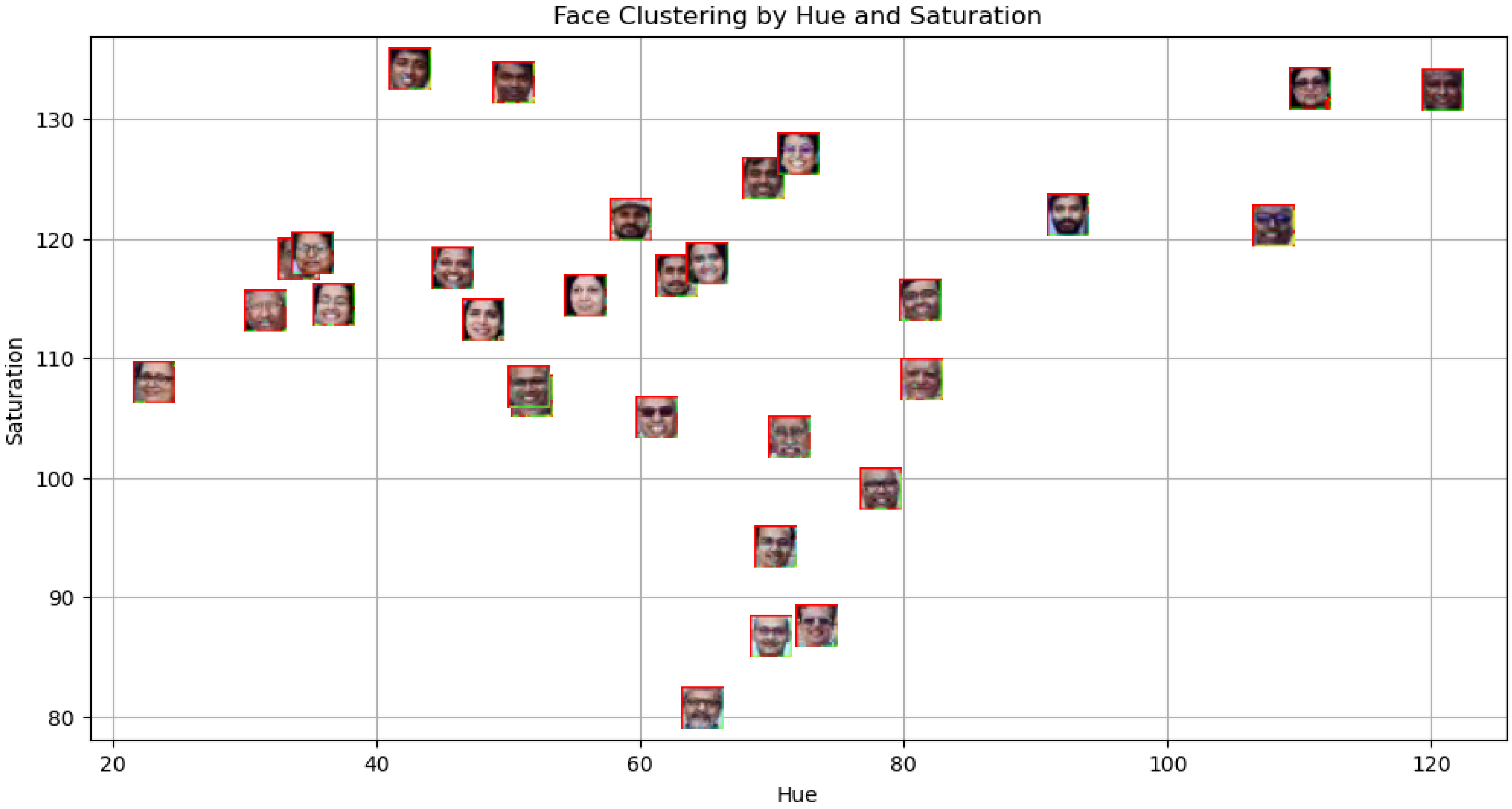
```python
font_thickness = 2  ## Thickness of the text


# Iterating through rectangles of detected faces
for (x, y, w, h) in faces_rect:
    cv2.rectangle(img, (x, y), (x+w, y+h), (0, 0, 255), 2)
    # Use cv2.putText to add the text to the image, Use text, font, font_scale, font_color, font_thickness here
    cv2.putText(img, text, (10, 30), font, font_scale, font_color, font_thickness)

## Display the image and window title should be "Total number of face detected are #"
plt.figure(figsize=(10, 8))
plt.imshow(cv2.cvtColor(img, cv2.COLOR_BGR2RGB))  # Convert BGR to RGB for correct colors
plt.title("Total number of faces detected are " + str(len(faces_rect)))
plt.axis('off')
plt.show()
#cv2.waitKey(0)
#cv2.destroyAllWindows()
```

Total number of faces detected are 30



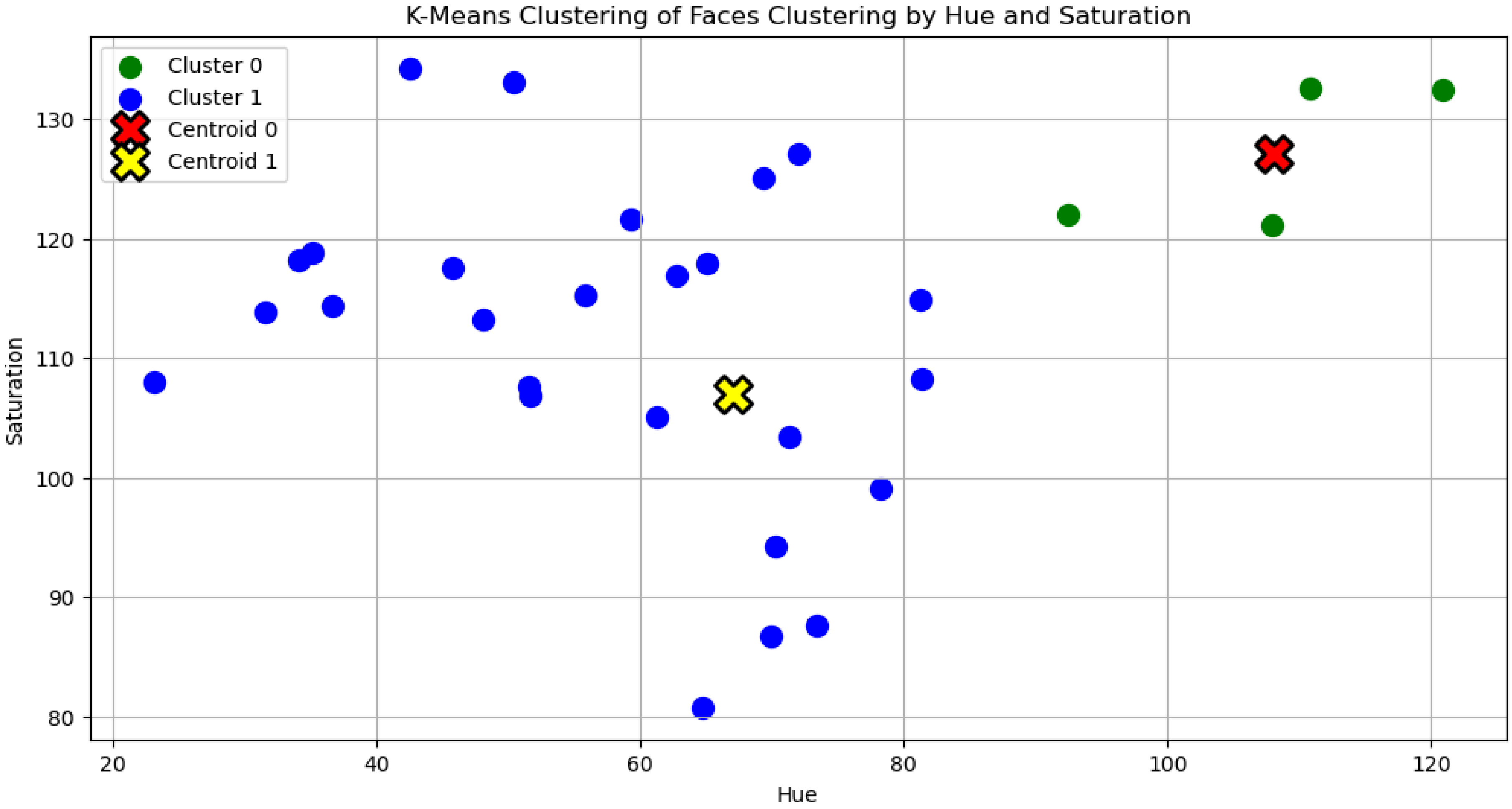
In [3]:
```
from matplotlib.offsetbox import OffsetImage, AnnotationBbox
# Extract face region features (Hue and Saturation)
img_hsv = cv2.cvtColor(img, cv2.COLOR_BGR2HSV) ## call the img and convert it from BGR to HSV and store in img_hsv
hue_saturation = []
face_images = []  # To store detected face images

for (x, y, w, h) in faces_rect:
```

```python
    face = img_hsv[y:y + h, x:x + w]
    hue = np.mean(face[:, :, 0])
    saturation = np.mean(face[:, :, 1])
    hue_saturation.append((hue, saturation))
    face_images.append(face)

hue_saturation = np.array(hue_saturation)

## Perform k-Means clustering on hue_saturation and store in kmeans
kmeans = KMeans(n_clusters=3, random_state=42)
kmeans.fit(hue_saturation)
centroids = kmeans.cluster_centers_
labels = kmeans.labels_

# Create a figure and axis
fig, ax = plt.subplots(figsize=(12, 6))

# Plot the clustered faces with custom markers
for i, (x,y,w,h ) in enumerate(faces_rect):
    im = OffsetImage(cv2.cvtColor(cv2.resize(face_images[i], (20, 20)), cv2.COLOR_HSV2RGB))
    ab = AnnotationBbox(im, (hue_saturation[i, 0], hue_saturation[i, 1]), frameon=False, pad=0)
    ax.add_artist(ab)
    plt.plot(hue_saturation[i, 0], hue_saturation[i, 1])


## Put x label
plt.xlabel("Hue")
## Put y label
plt.ylabel("Saturation")
## Put title
plt.title("Face Clustering by Hue and Saturation")
## Put grid
plt.grid(True)
## show the plot
plt.show()
```




```
In [4]: # Create an empty list to store legend labels
legend_labels = []

# Create lists to store points for each cluster
cluster_0_points = []
cluster_1_points = []

# Your code for scatter plot goes here
fig, ax = plt.subplots(figsize=(12, 6))
for i, (x, y, w, h) in enumerate(faces_rect):
```

```
    if kmeans.labels_[i] == 0:
        cluster_0_points.append((hue_saturation[i, 0], hue_saturation[i, 1]))
    else:
        cluster_1_points.append((hue_saturation[i, 0], hue_saturation[i, 1]))


cluster_0_points = np.array(cluster_0_points)
# Plot points for cluster 0 in green
plt.scatter(cluster_0_points[:, 0], cluster_0_points[:, 1], color='green', label='Cluster 0', s=100)


cluster_1_points = np.array(cluster_1_points)
# Plot points for cluster 1 in blue
plt.scatter(cluster_1_points[:, 0], cluster_1_points[:, 1], color='blue', label='Cluster 1', s=100)

# Calculate and plot centroids
centroid_0 = kmeans.cluster_centers_[0]
centroid_1 = kmeans.cluster_centers_[1]

# Plot both the centroid for cluster 0 and cluster 1
plt.scatter(centroid_0[0], centroid_0[1], color='red', marker='X', s=300, label='Centroid 0', edgecolors='black', l
plt.scatter(centroid_1[0], centroid_1[1], color='yellow', marker='X', s=300, label='Centroid 1', edgecolors='black'

## Put x label
plt.xlabel("Hue")
## Put y label
plt.ylabel("Saturation")
## Put title
plt.title("K-Means Clustering of Faces Clustering by Hue and Saturation")
## Add a legend
plt.legend()
## Add grid
plt.grid(True)
## Show the plot
plt.show()
```



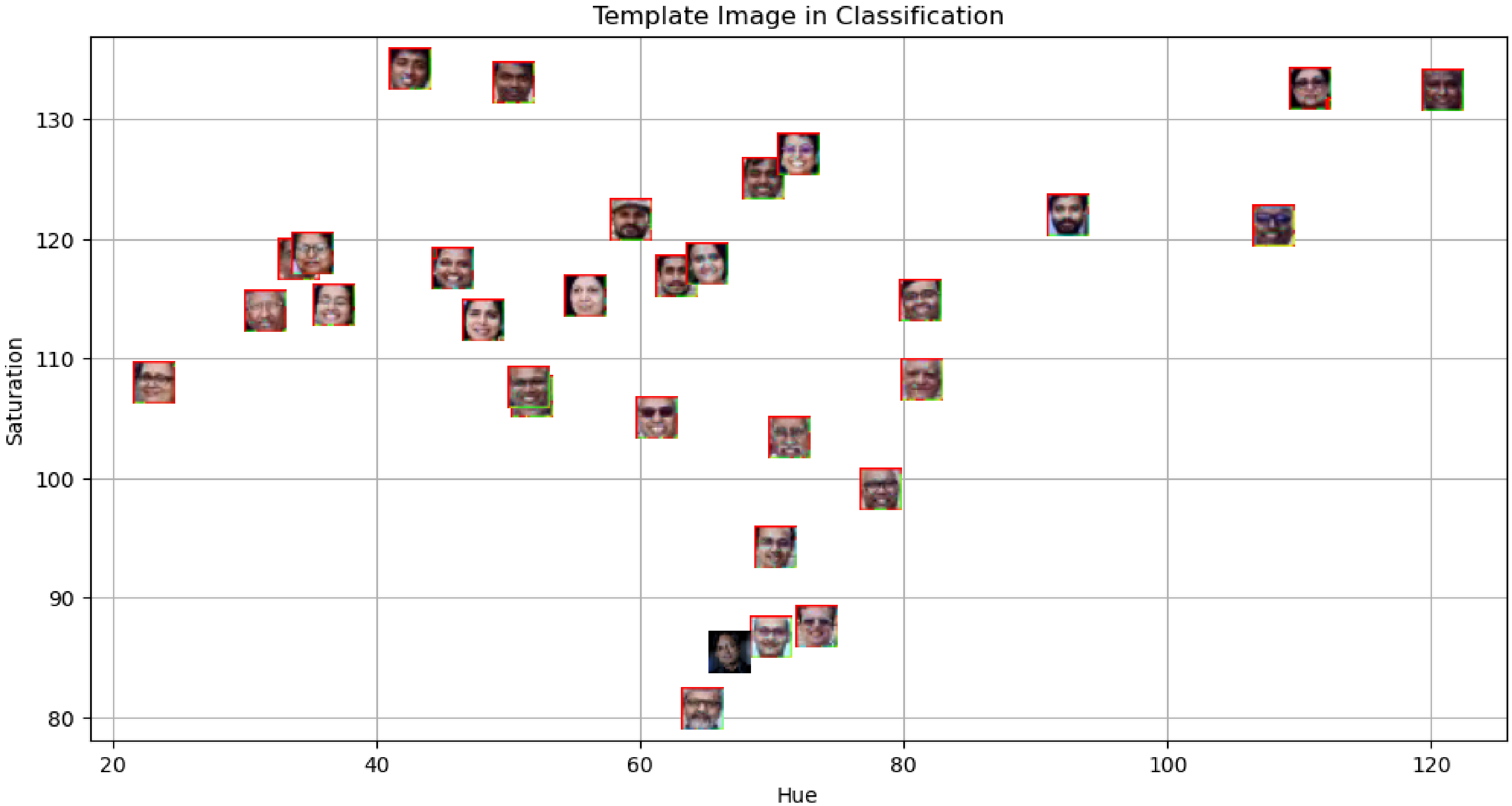
In [5]:

```
## Read the class of the template image 'Dr_Shashi_Tharoor.jpg' using cv2 and store it in template_img
template_img = cv2.imread('Dr_Shashi_Tharoor.jpg')
# Detect face  in the template image after converting it to gray and store it in template_faces
template_faces = face_cascade.detectMultiScale(cv2.cvtColor(template_img, cv2.COLOR_BGR2GRAY), 1.05, 4, minSize=(25
# Draw rectangles around the detected faces
for (x, y, w, h) in template_faces:
    cv2.rectangle(template_img, (x, y), (x + w, y + h), (0, 255, 0), 3)
##cv2.imshow('Template Image with Detected Faces', template_img)
img_rgb = cv2.cvtColor(template_img, cv2.COLOR_BGR2RGB)
plt.figure(figsize=(6,6))
```

```
plt.imshow(img_rgb)
plt.axis("off")
plt.show()
##cv2.waitKey(0)
##cv2.destroyAllWindows()
```

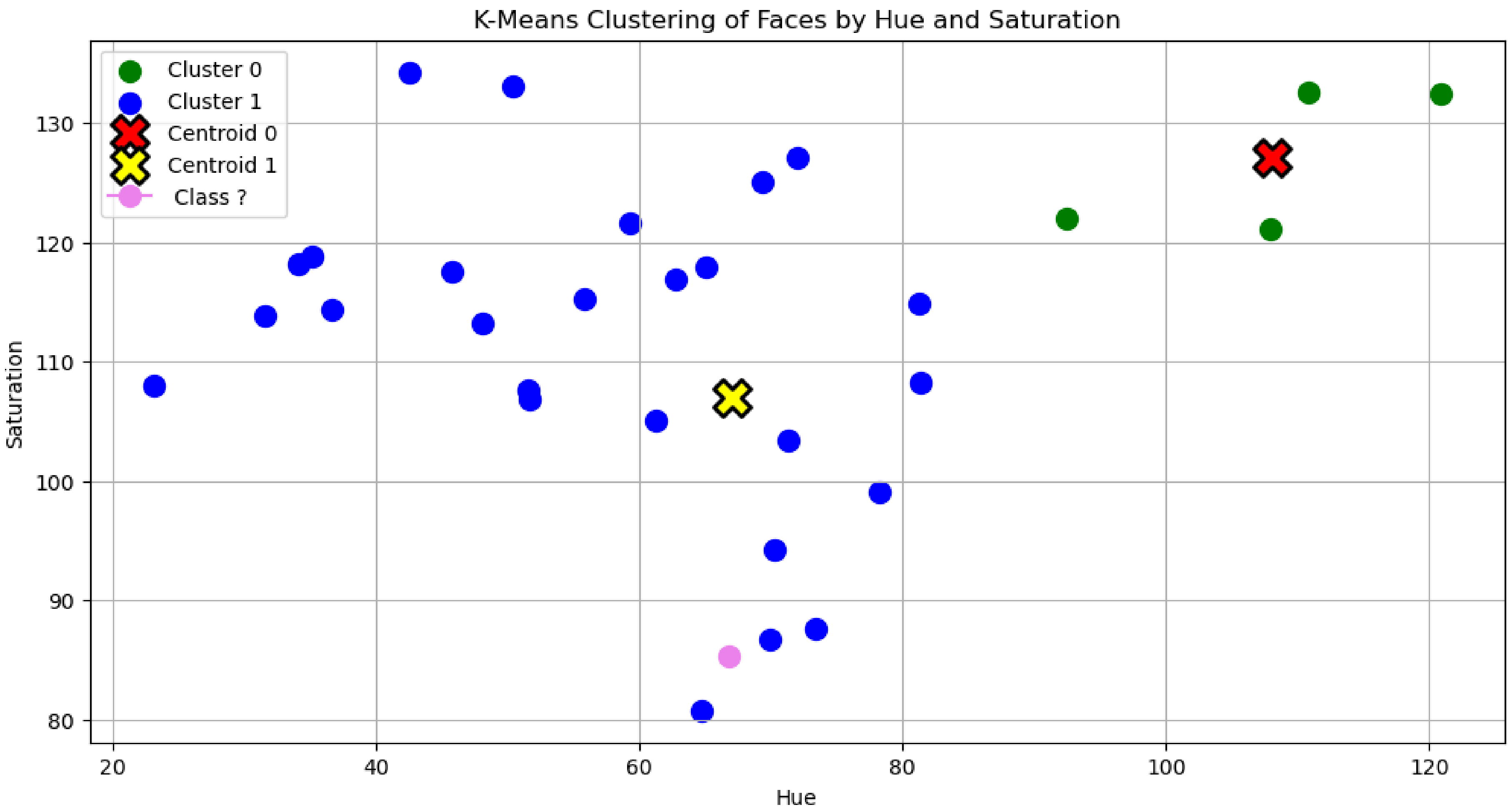
In [6]:
```
# Convert the template image to HSV color space and store it in template_hsv
template_hsv = cv2.cvtColor(template_img, cv2.COLOR_BGR2HSV)

# Extract hue and saturation features from the template image as we did it for detected faces.
template_hue = np.mean(template_hsv[:, :, 0])
```

```python
template_saturation = np.mean(template_hsv[:, :, 1])

# Predict the cluster label for the template image and store it in template_label
template_label = kmeans.predict([[template_hue, template_saturation]])[0]

# Create a figure and axis for visualization
fig, ax = plt.subplots(figsize=(12, 6))

# Plot the clustered faces with custom markers (similar to previous code)
for i, (x, y, w, h) in enumerate(faces_rect):
    color = 'red' if kmeans.labels_[i] == 0 else 'blue'
    im = OffsetImage(cv2.cvtColor(cv2.resize(face_images[i], (20, 20)), cv2.COLOR_HSV2RGB))
    ab = AnnotationBbox(im, (hue_saturation[i, 0], hue_saturation[i, 1]), frameon=False, pad=0)
    ax.add_artist(ab)
    plt.plot(hue_saturation[i, 0], hue_saturation[i, 1], 'o', markersize=5, color=color)

# Plot the template image in the respective cluster
if template_label == 0:
    color = 'red'
else:
    color = 'blue'
im = OffsetImage(cv2.cvtColor(cv2.resize(template_img, (20, 20)), cv2.COLOR_BGR2RGB))
ab = AnnotationBbox(im, (template_hue, template_saturation), frameon=False, pad=0)
ax.add_artist(ab)

## Put x label
plt.xlabel("Hue")
## Put y label
plt.ylabel("Saturation")
## Put title
plt.title("Template Image in Classification")
## Add grid
plt.grid(True)
## show plot
plt.show()
```



In [7]:
```
# Create an empty list to store legend labels
legend_labels = []

# Create lists to store points for each cluster
cluster_0_points = []
cluster_1_points = []

# Your code for scatter plot goes here
fig, ax = plt.subplots(figsize=(12, 6))
for i, (x, y, w, h) in enumerate(faces_rect):
```

```python
    if kmeans.labels_[i] == 0:
        cluster_0_points.append((hue_saturation[i, 0], hue_saturation[i, 1]))
    else:
        cluster_1_points.append((hue_saturation[i, 0], hue_saturation[i, 1]))

# Plot points for cluster 0 in green
cluster_0_points = np.array(cluster_0_points)
plt.scatter(cluster_0_points[:, 0], cluster_0_points[:, 1], color='green', label='Cluster 0', s=100)

# Plot points for cluster 1 in blue
cluster_1_points = np.array(cluster_1_points)
plt.scatter(cluster_1_points[:, 0], cluster_1_points[:, 1], color='blue', label='Cluster 1', s=100)

# Calculate and plot centroids for both the clusters
centroid_0 = kmeans.cluster_centers_[0]
centroid_1 = kmeans.cluster_centers_[1]
plt.scatter(centroid_0[0], centroid_0[1], color='red', marker='X', s=300, label='Centroid 0', edgecolors='black', l
plt.scatter(centroid_1[0], centroid_1[1], color='yellow', marker='X', s=300, label='Centroid 1', edgecolors='black'
plt.plot(template_hue, template_saturation, marker='o', c= 'violet',markersize= 10, label=' Class ?' )

## Put x label
plt.xlabel("Hue")
## Put y label
plt.ylabel("Saturation")
## Put title
plt.title("K-Means Clustering of Faces by Hue and Saturation")
## Add a legend
plt.legend()
## Add grid
plt.grid(True)
## show the plot
plt.show()
                                             ## End of the lab 5 ##
```



Report:

Answer the following questions within your report:

1. What are the common distance metrics used in distance-based classification algorithms?

Some of the common distance metrics used in distance-based classification algorithms include:

- Euclidean distance
- Manhattan distance
- Mahalanobis distance
- Chebyshev distance
- Minkowski distance
- Cosine distance
- Hamming Distance

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2. What are some real-world applications of distance-based classification algorithms?

Some real-world applications of distance-based classification algorithms include:

- Image classification and face recognition
- Document and spam classification
- Customer Segmentation
- Medical diagnosis
- Fraud and anomaly detection

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3. Explain various distance metrics.

- Euclidean: Straight-line distance between two points; most common.
- Manhattan: Sum of absolute coordinate differences (grid/axis distance).
- Mahalanobis: Distance from a distribution; considers variance and correlations.
- Chebyshev: Maximum difference along any dimension.
- Minkowski: Generalized form (p-norm); includes Euclidean (p=2) and Manhattan (p=1).
- Cosine: Measures angle between vectors; compares orientation not magnitude.
- Hamming: Measures the number of positions at which corresponding symbols are different.

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4. What is the role of cross validation in model performance?

The role of cross validation in model performance is to assess how well a model genralizes to new and unseen data to prevent overfitting.

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5. Explain variance and bias in terms of KNN?

k controls the bias-variance trade-off in KNN.

- Small k (e.g., k=1):
  - Low bias, high variance
  - Very sensitive to noise (overfitting)
- Large k:
  - High bias, low variance
  - Smoother decision boundary (underfitting)