Otsu Thresholding

How to run the file:

- **Environment:**
  - The code is written in Python using the OpenCV library and executed in the VS Code IDE.

- **Execution Instructions:**
  - Open the code in **VS Code**.
  - Run all the cells sequentially by selecting the **"Run All"** option or executing them one by one.

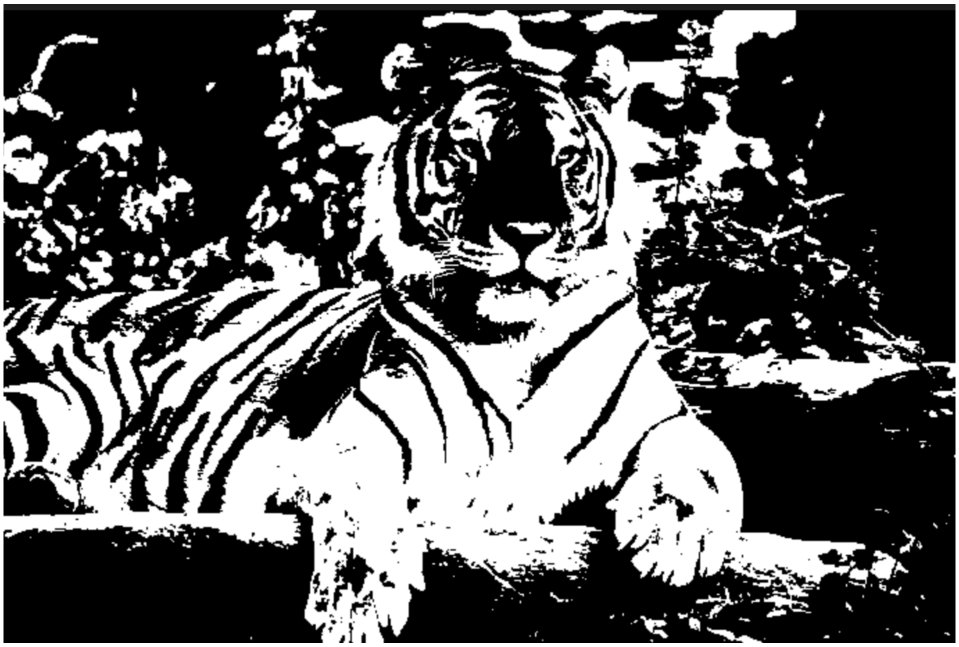
- **Path Configuration:**
  - The files will be downloaded to the directory specified in the code.
  - Currently, the download path is set to:

    "/Users/komalbagwe/Documents/OtsuThreshold"
  - Please update the path in the code to match your local system's directory structure before running.

Outputs:

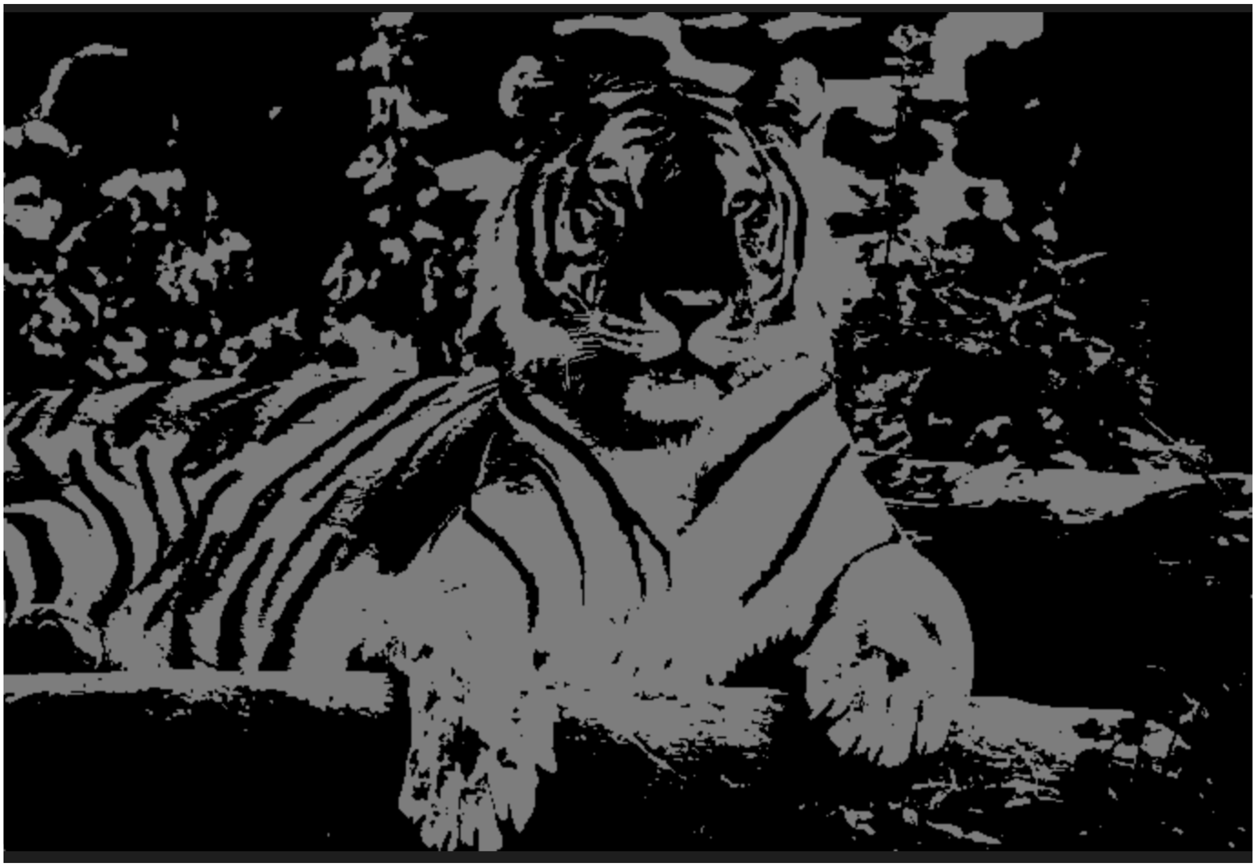
Tiger:

- **2 Regions:**



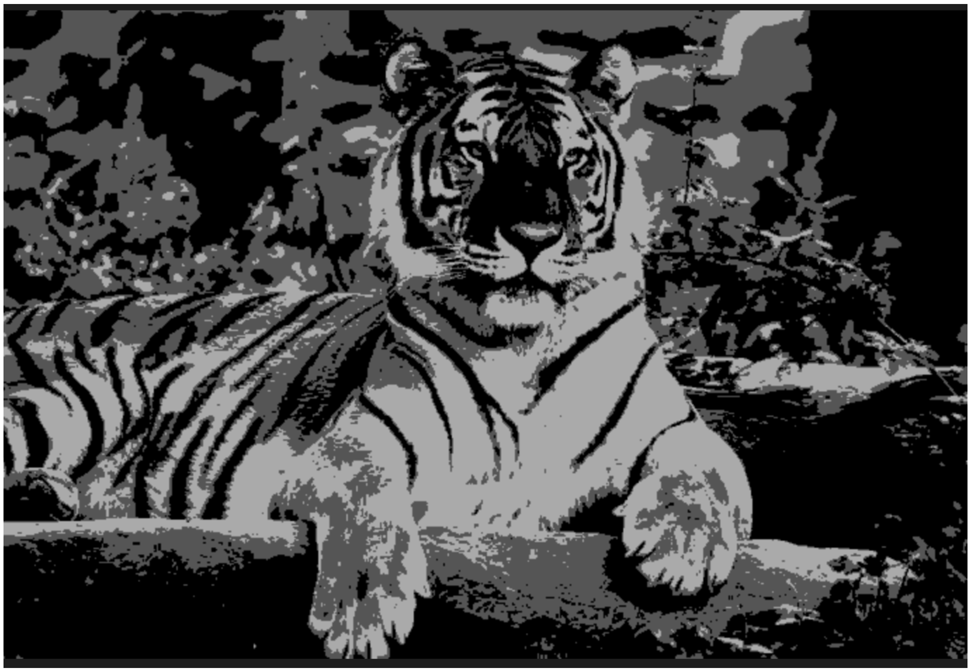
Total Variance: 1321.495701465642
Variance Background: 1048.8616596019845
Variance Foreground: 1820.4866618389544
Optimal Threshold (2 regions): 107

- **3 Region**

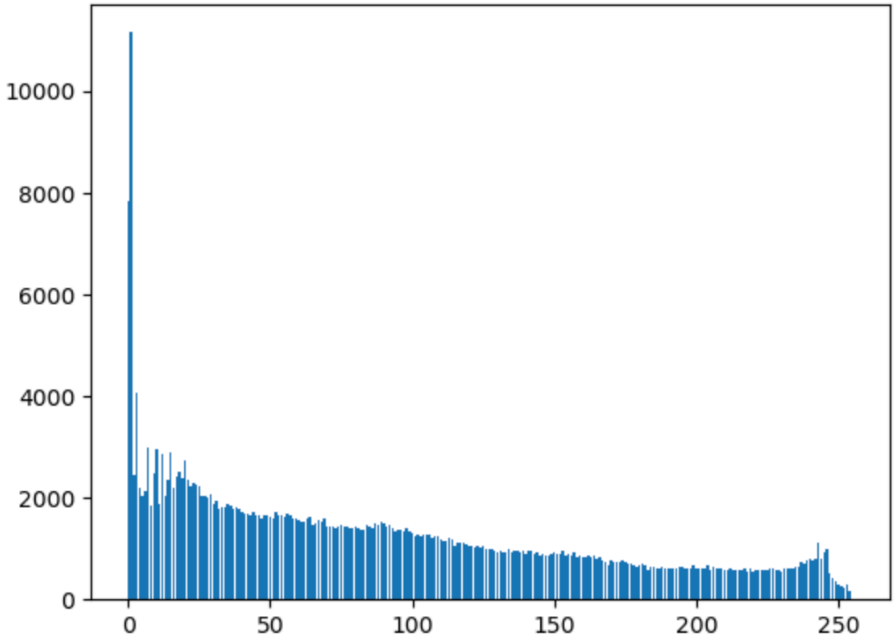


```
Total Variance:  420354567.679206
Variance 1:  1048.8616596019845
Variance 2:  1820.4866618389544
Variance 3:  -0.0
Optimal Thresholds (3 regions): (107, 254)
```

- **4 Region:**



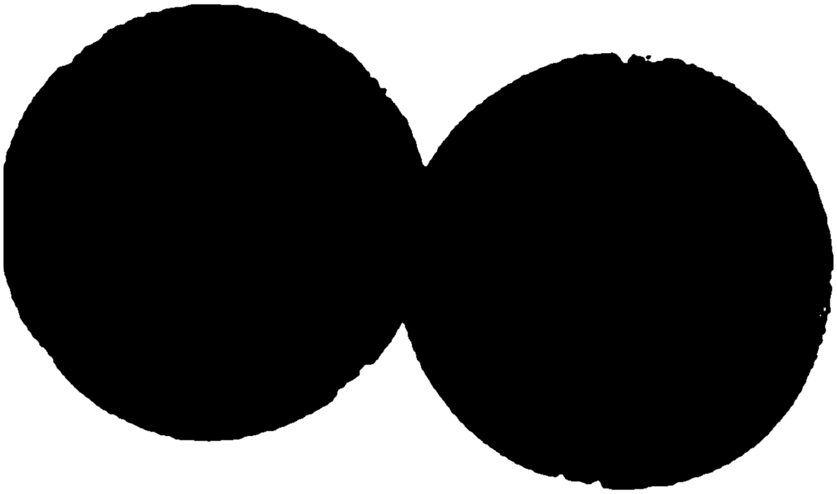
```
Total Variance:  180965973.79668894
Variance 1:  383.69854809316024
Variance 2:  605.3636775863564
Variance 3:  908.17836002217
Variance 4:  -0.0
Optimal Thresholds (4 regions): (64, 151, 254)
```



Global Histogram

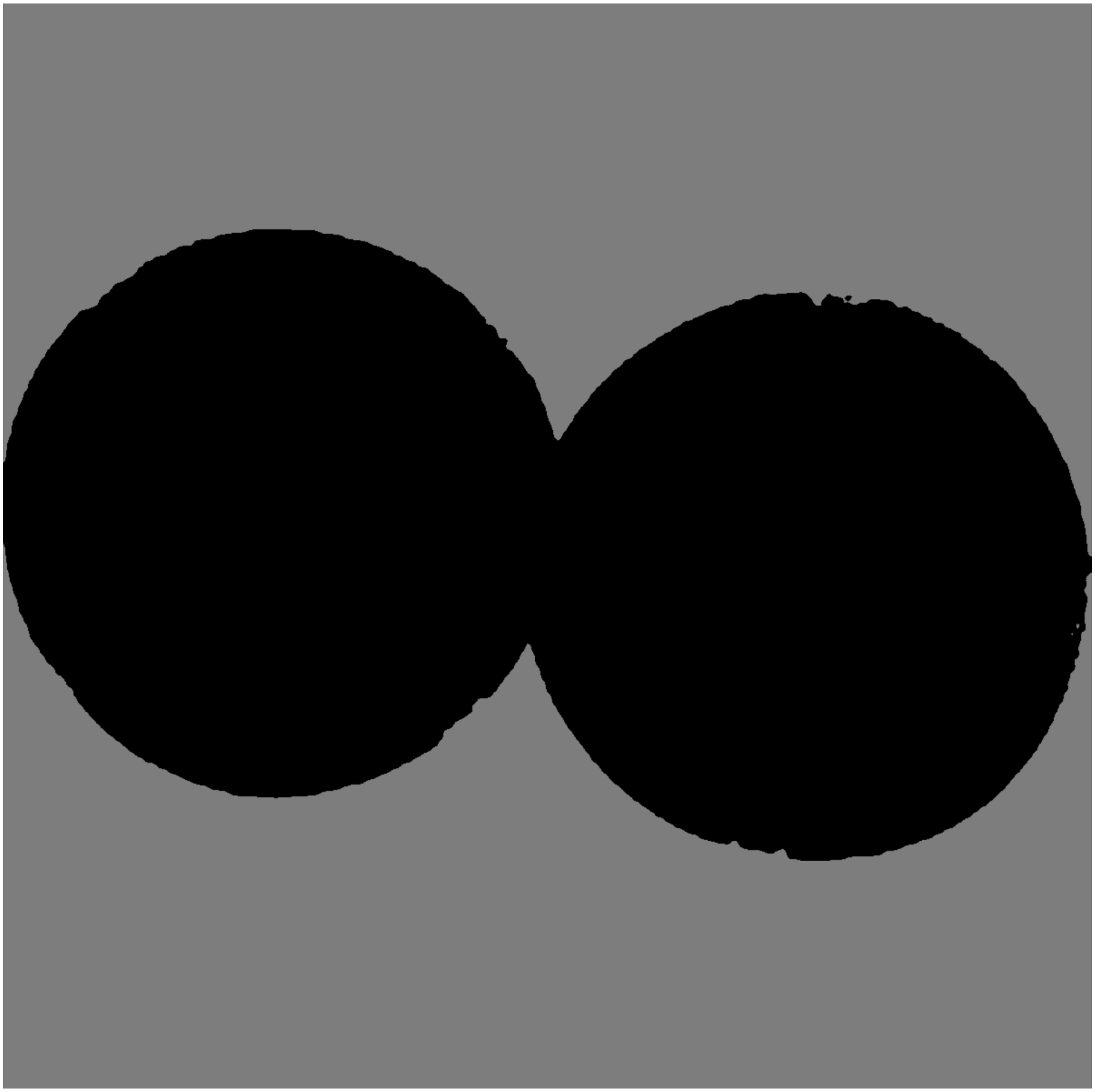
Basket Balls:

- **2 Regions:**



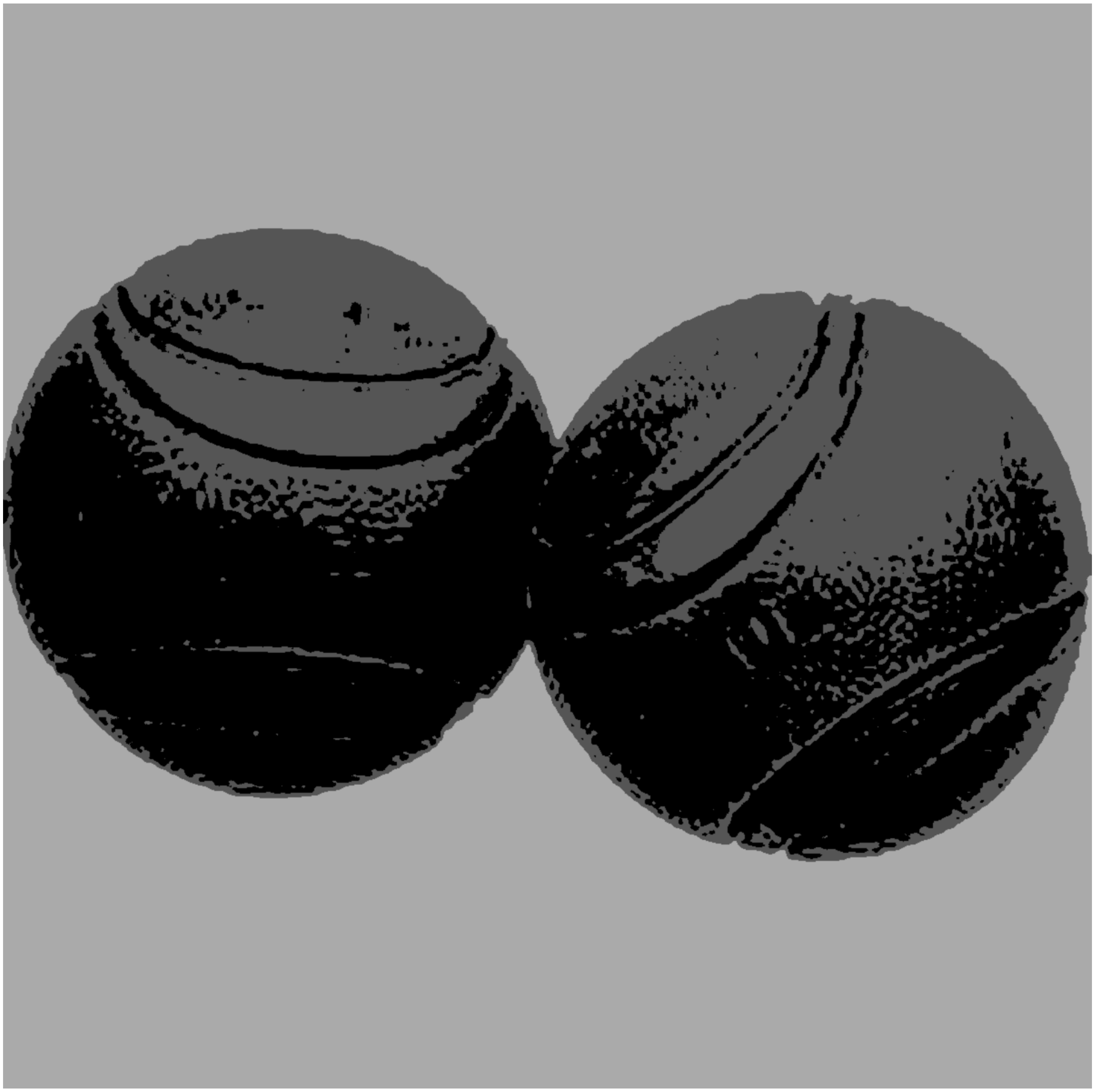
Variance Background: 382.43225054759506
Variance Foreground: 42.86177905161761
Total Variance: 184.7546019457958
Optimal Threshold (2 regions): 175

- **3 Regions:**

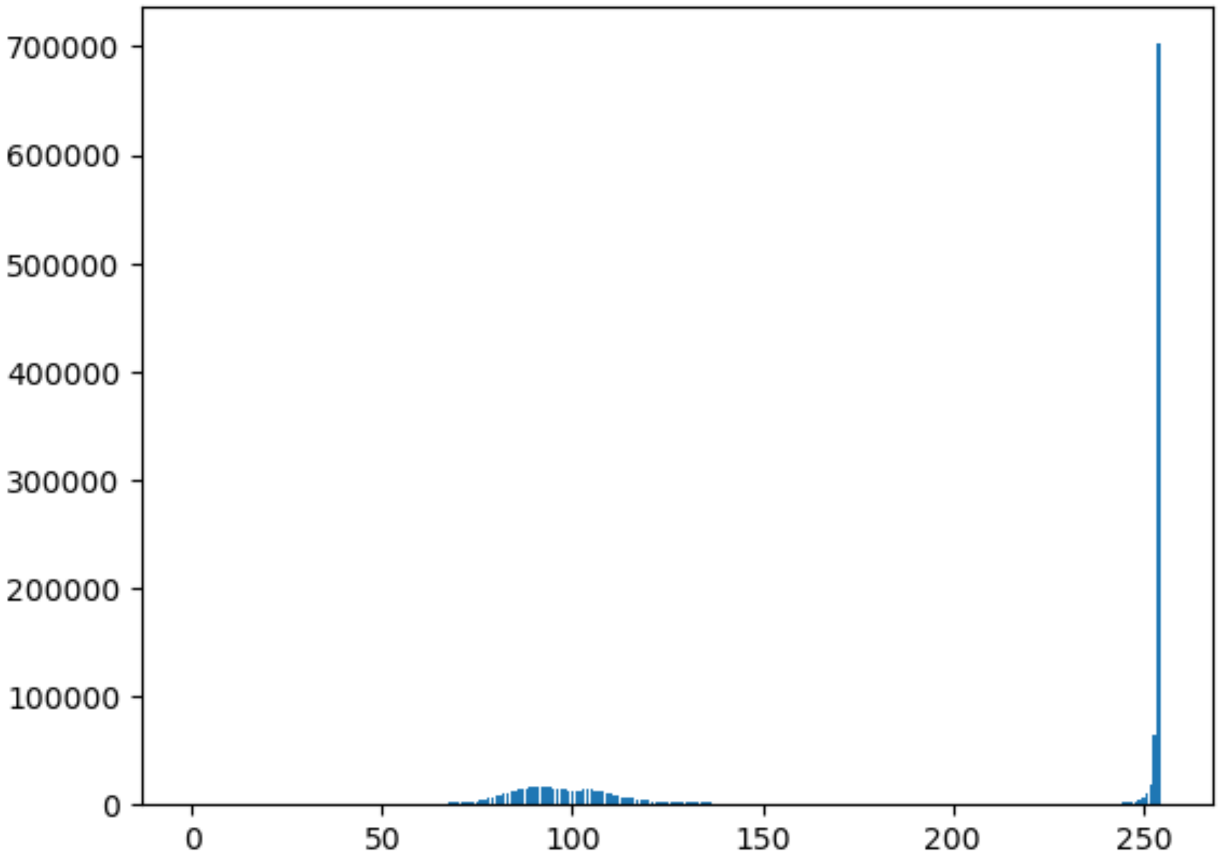


```
Variance 1:  382.43225054759506
Variance 2:  42.86177905161762
Variance 3:  -0.0
Total Variance:  266046626.80194592
Optimal Thresholds (3 regions): (175, 254)
```

- **4 Regions:**



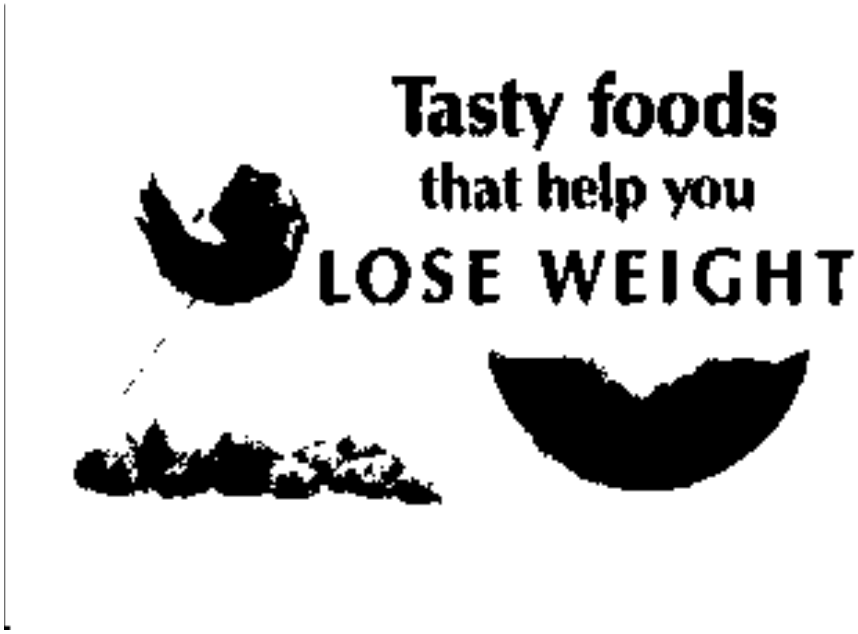
```
Variance 1:  163.50118045512397
Variance 2:  224.46328408450253
Variance 3:  30.75578948851017
Variance 4:  -0.0
Total Variance:  139525869.06259522
Optimal Thresholds (4 regions): (100, 184, 254)
```



Global Histogram

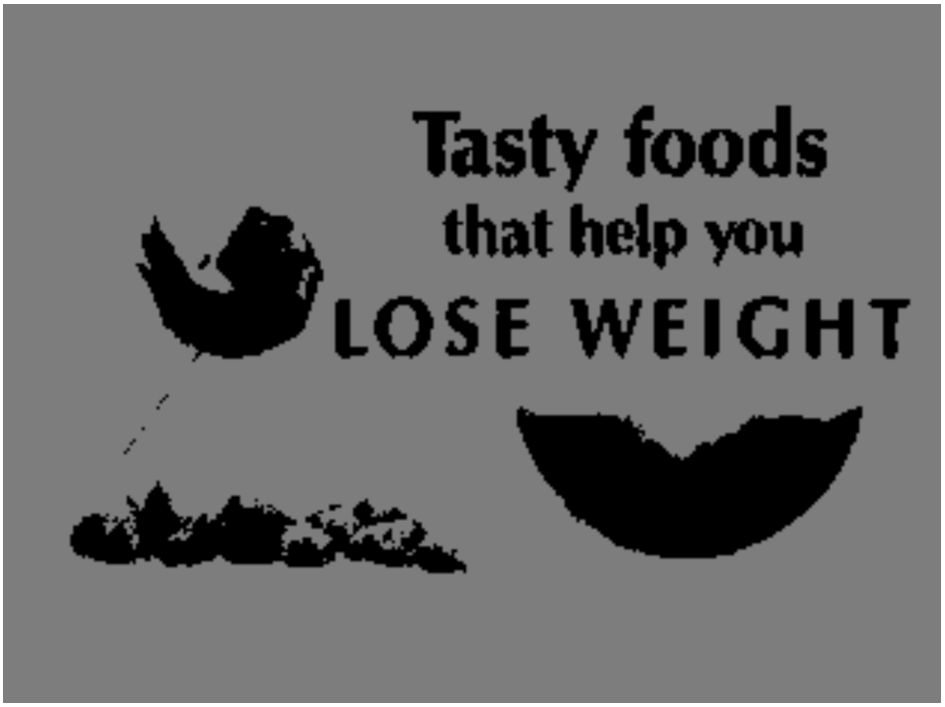
Data13:

- **2 Regions:**



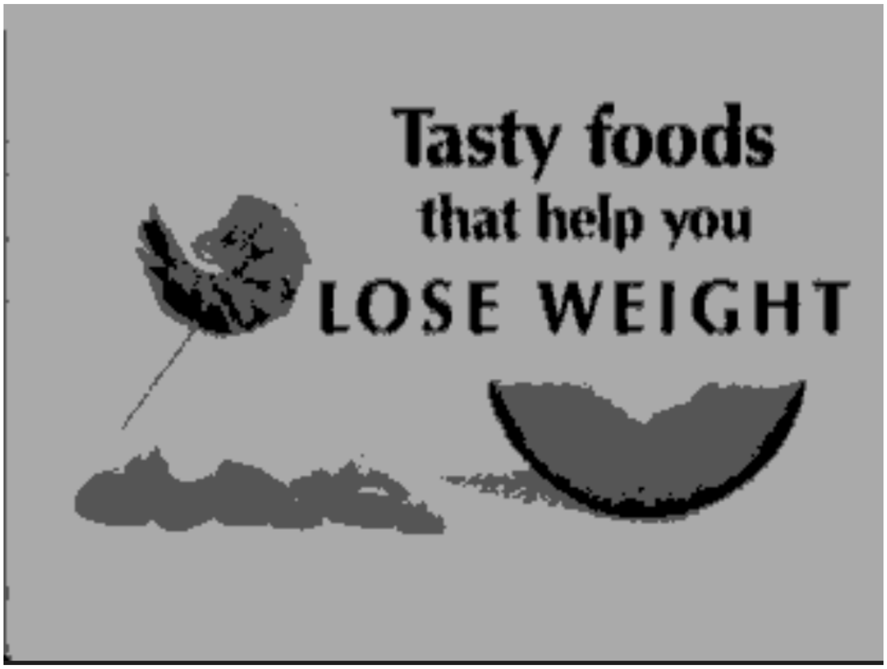
```
Variance Background:  2678.2900960716574
Variance Foreground:  128.03975622247165
Total Variance:  516.9529330494724
Optimal Threshold (2 regions): 186
```

- **3 Regions:**

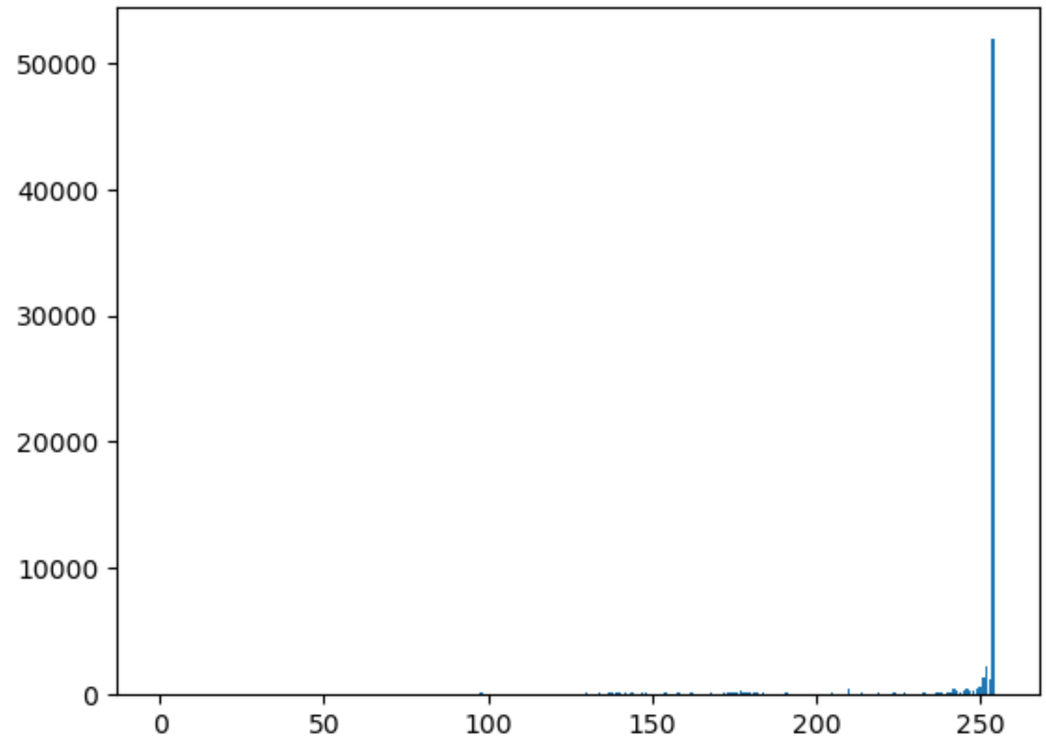


```
Variance 1:  2678.2900960716574
Variance 2:  128.03975622247165
Variance 3:  -0.0
Total Variance:  39701985.25819949
Optimal Thresholds (3 regions): (186, 254)
```

- **4 Regions:**



Variance 1: 1150.018940220784
Variance 2: 665.1849493193927
Variance 3: 52.25441369998197
Variance 4: -0.0
Total Variance: 14069764.870658644
Optimal Thresholds (4 regions): (109, 206, 254)



Global Histogram

Source Code:

```
pip install opencv-python
```

```
Requirement already satisfied: opencv-python in
/opt/miniconda3/lib/python3.12/site-packages (4.10.0.84)
Requirement already satisfied: numpy>=1.21.2 in
/opt/miniconda3/lib/python3.12/site-packages (from opencv-python)
(1.26.4)
Note: you may need to restart the kernel to use updated packages.
```

```
pip install matplotlib
```

```
Requirement already satisfied: matplotlib in
/opt/miniconda3/lib/python3.12/site-packages (3.9.2)
Requirement already satisfied: contourpy>=1.0.1 in
/opt/miniconda3/lib/python3.12/site-packages (from matplotlib) (1.2.0)
Requirement already satisfied: cycler>=0.10 in
/opt/miniconda3/lib/python3.12/site-packages (from matplotlib)
(0.11.0)
Requirement already satisfied: fonttools>=4.22.0 in
/opt/miniconda3/lib/python3.12/site-packages (from matplotlib)
(4.51.0)
Requirement already satisfied: kiwisolver>=1.3.1 in
/opt/miniconda3/lib/python3.12/site-packages (from matplotlib) (1.4.4)
Requirement already satisfied: numpy>=1.23 in
/opt/miniconda3/lib/python3.12/site-packages (from matplotlib)
(1.26.4)
Requirement already satisfied: packaging>=20.0 in
/opt/miniconda3/lib/python3.12/site-packages (from matplotlib) (24.1)
Requirement already satisfied: pillow>=8 in
/opt/miniconda3/lib/python3.12/site-packages (from matplotlib)
(10.4.0)
Requirement already satisfied: pyparsing>=2.3.1 in
/opt/miniconda3/lib/python3.12/site-packages (from matplotlib) (3.1.4)
Requirement already satisfied: python-dateutil>=2.7 in
/opt/miniconda3/lib/python3.12/site-packages (from matplotlib) (2.9.0)
Requirement already satisfied: six>=1.5 in
/opt/miniconda3/lib/python3.12/site-packages (from python-
dateutil>=2.7->matplotlib) (1.16.0)
Note: you may need to restart the kernel to use updated packages.
```

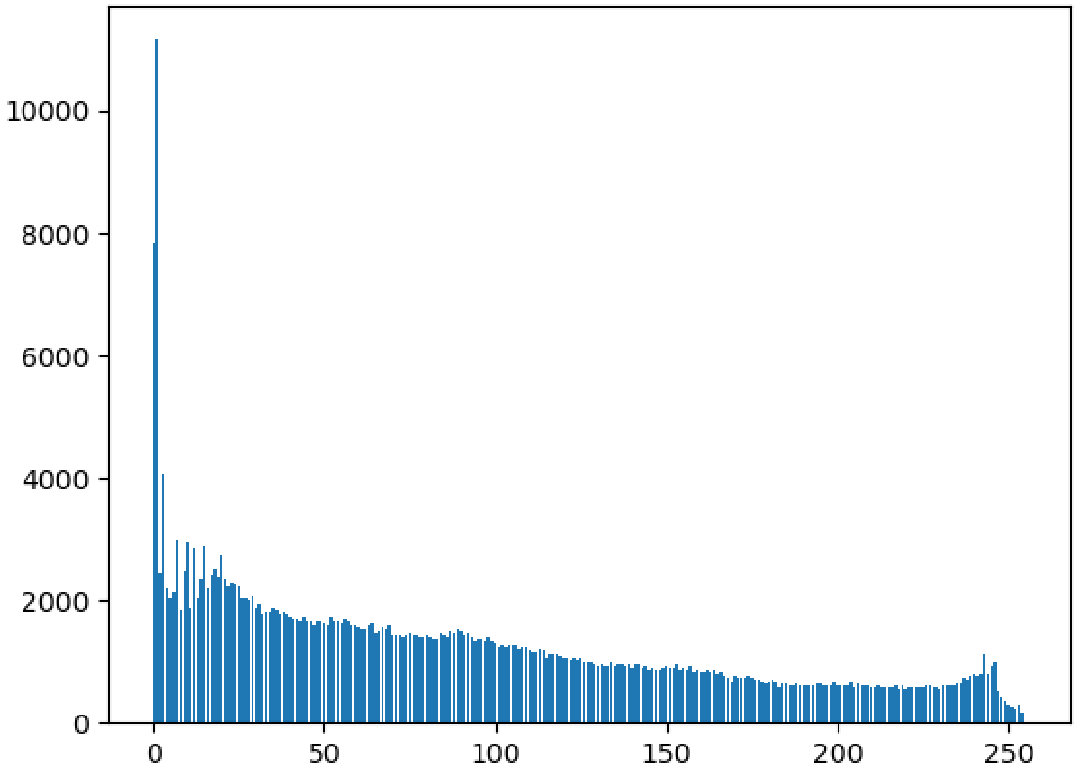
```
pip install Pillow
```

```
Requirement already satisfied: Pillow in
/opt/miniconda3/lib/python3.12/site-packages (10.4.0)
Note: you may need to restart the kernel to use updated packages.
```

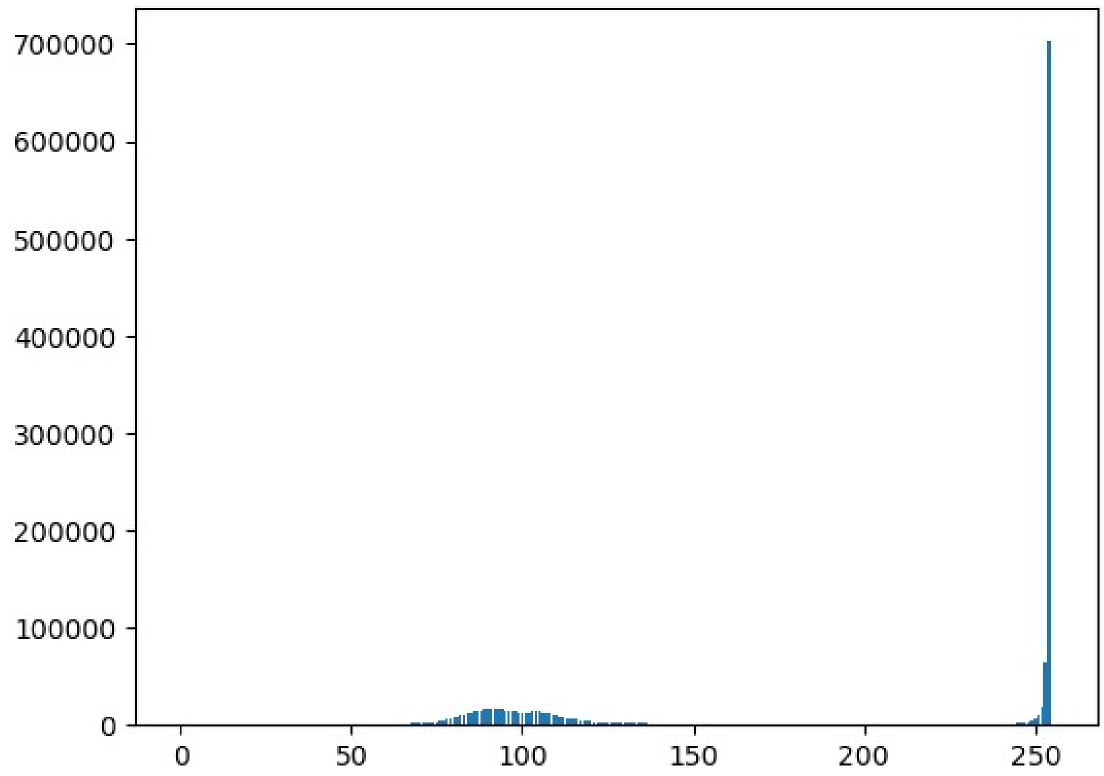
```python
def histogram(img):
  hist = [0] * 256
  for i in range(0, len(img)):
    for j in range(0, len(img[0])):
```

```
   hist[img[i][j]] += 1
 return hist

def countPixels(hist):
 count = 0
 for i in range(0, len(hist)):
  if hist[i] >= 0:
   count += hist[i]
 return count

def threshold_with_two_regions(new_gray_image):
 hist = histogram(new_gray_image)
 plt.bar(np.arange(0, 256), hist)
 plt.show()
 count_pixels = countPixels(hist)
 min_var = float('inf')
 threshold = 0
 var_b = 0
 var_f = 0
 w_b = 0
 w_f = 0
 sum_b = 0
 for t in range(0, len(hist)):
  # Calculate weights
  w_b += hist[t]
  if w_b == 0:
   continue
  w_f = countPixels(hist) - w_b
  if w_f == 0:
   break

  sum_b += t * hist[t]
  sum_f = (np.sum(np.arange(0, 256) * hist)) - sum_b
   # Calculate means
  mu_b = sum_b / w_b
  mu_f = sum_f / w_f

  # Calculate variances
  var_b = np.sum((np.arange(0, t + 1) - mu_b) ** 2 * hist[:t + 1]) /
w_b

  var_f = np.sum((np.arange(t + 1, 256) - mu_f) ** 2 * hist[t + 1:])
/ w_f

  # Calculate weighted sum of variances
  total_var = ((w_b/count_pixels) * (var_b)) + ((w_f/count_pixels) *
(var_f))

  # Update thresholds if variance is minimized
  if total_var < min_var:
   min_var = total_var
   threshold = t

 print("Total Variance: ",min_var)
 return threshold



def threshold_with_three_regions(image):
  hist = histogram(image)
  # Precompute cumulative sums for efficiency
  cum_sum = np.cumsum(hist)
  cum_mean = np.cumsum(hist * np.arange(256))


  min_var = float('inf')
  optimal_thresholds = (0, 0)

  # Iterate over all possible doubles of thresholds
  for t1 in range(1, 254):
      for t2 in range(t1 + 1, 255):
          # Calculate weights
          w1 = cum_sum[t1]
          w2 = cum_sum[t2] - cum_sum[t1]
          w3 = 1 - cum_sum[t2]

          # Skip if any weight is zero
          if w1 == 0 or w2 == 0 or w3 == 0:
              continue

          # Calculate means
          mu1 = cum_mean[t1] / w1
          mu2 = (cum_mean[t2] - cum_mean[t1]) / w2
          mu3 = (cum_mean[255] - cum_mean[t2]) / w3

          # Calculate variances
          var1 = np.sum((np.arange(0, t1 + 1) - mu1) ** 2 * hist[:t1
+ 1]) / w1
          var2 = np.sum((np.arange(t1 + 1, t2 + 1) - mu2) ** 2 *
hist[t1 + 1:t2 + 1]) / w2
          var3 = np.sum((np.arange(t2 + 1, 256) - mu3) ** 2 *
hist[t2 + 1:]) / w3


          # Calculate weighted sum of variances
          total_var = w1 * var1 + w2 * var2 + w3 * var3

          # Update thresholds if variance is minimized
          if total_var < min_var:
              min_var = total_var
              optimal_thresholds = (t1, t2)


  print("Total Variance: ",min_var)
  return optimal_thresholds


def threshold_with_four_regions(image):
  hist = histogram(image)

  # Precompute cumulative sums for efficiency
  cum_sum = np.cumsum(hist)
  cum_mean = np.cumsum(hist * np.arange(256))

  min_var = float('inf')
  optimal_thresholds = (0, 0, 0)

  # Iterate over all possible triplets of thresholds
  for t1 in range(1, 253):
      for t2 in range(t1 + 1, 254):
          for t3 in range(t2 + 1, 255):
              # Calculate weights
              w1 = cum_sum[t1]
              w2 = cum_sum[t2] - cum_sum[t1]
              w3 = cum_sum[t3] - cum_sum[t2]
              w4 = 1 - cum_sum[t3]

              # Skip if any weight is zero
              if w1 == 0 or w2 == 0 or w3 == 0 or w4 == 0:
                  continue

              # Calculate means
              mu1 = cum_mean[t1] / w1
              mu2 = (cum_mean[t2] - cum_mean[t1]) / w2
              mu3 = (cum_mean[t3] - cum_mean[t2]) / w3
              mu4 = (cum_mean[255] - cum_mean[t3]) / w4

              # Calculate variances
              var1 = np.sum((np.arange(0, t1 + 1) - mu1) ** 2 *
hist[:t1 + 1]) / w1
              var2 = np.sum((np.arange(t1 + 1, t2 + 1) - mu2) ** 2 *
hist[t1 + 1:t2 + 1]) / w2
              var3 = np.sum((np.arange(t2 + 1, t3 + 1) - mu3) ** 2 *
hist[t2 + 1:t3 + 1]) / w3
              var4 = np.sum((np.arange(t3 + 1, 256) - mu4) ** 2 *
hist[t3 + 1:]) / w4


              # Calculate weighted sum of variances
              total_var = w1 * var1 + w2 * var2 + w3 * var3 + w4 *
```

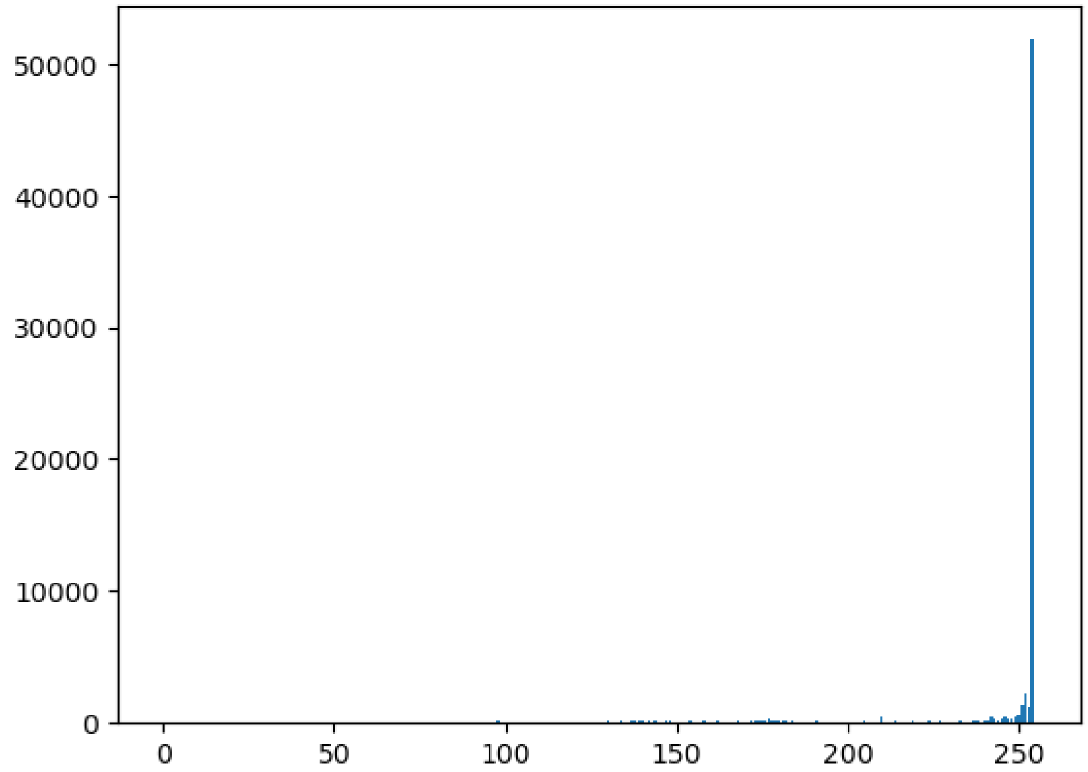
```
var4


                # Update thresholds if variance is minimized
                if total_var < min_var:
                    min_var = total_var
                    optimal_thresholds = (t1, t2, t3)


    print("Total Variance: ",min_var)
    return optimal_thresholds

import os
import shutil
def move_to_folder(file_path):
    downloads_path = os.path.join(os.path.expanduser("~"),
"/Users/komalbagwe/Documents/OtsuThreshold")
    shutil.move(file_path, os.path.join(downloads_path,
os.path.basename(file_path)))
    print(f"Moved {file_path} to OtsuThreshold folder.")

import cv2
import numpy as np
import matplotlib.pyplot as plt


# Load the image
paths = ["tiger1.bmp", "basket_balls.bmp", "data13.bmp"]
for idx, path in enumerate(paths):
    img = cv2.imread(path)
    if img is None:
        print(f"Error: Unable to load image at {path}")
        continue


    # Convert to grayscale
    gray_img = np.dot(img, [0.299, 0.587, 0.114])
    gray_img = np.uint8(gray_img)


    # Apply Otsu thresholding for 2 regions
    optimal_threshold_two_region =
threshold_with_two_regions(gray_img)
    _, binary_image_2_region = cv2.threshold(gray_img,
optimal_threshold_two_region, 255, cv2.THRESH_BINARY)

    # Apply Otsu thresholding for 3 regions
    optimal_threshold_three_region =
threshold_with_three_regions(gray_img)
    binary_image_3_region = np.zeros_like(gray_img)
    t1, t2 = optimal_threshold_three_region
    binary_image_3_region[gray_img <= t1] = 0  # Class 1
    binary_image_3_region[(gray_img > t1) & (gray_img <= t2)] = 128  #
Class 2
    binary_image_3_region[gray_img > t2] = 255  # Class 3

    # Apply Otsu thresholding for 4 regions
    optimal_threshold_four_region =
threshold_with_four_regions(gray_img)
    binary_image_4_region = np.zeros_like(gray_img)
    t1, t2, t3 = optimal_threshold_four_region
    binary_image_4_region[gray_img <= t1] = 0  # Class 1
    binary_image_4_region[(gray_img > t1) & (gray_img <= t2)] = 85  #
Class 2
    binary_image_4_region[(gray_img > t2) & (gray_img <= t3)] = 170  #
Class 3
    binary_image_4_region[gray_img > t3] = 255  # Class 4

    # Save and download the results
    output_filename_2_region = f"otsu_2_region_out_{paths[idx]}"
    output_filename_3_region = f"otsu_3_region_out_{paths[idx]}"
    output_filename_4_region = f"otsu_4_region_out_{paths[idx]}"

    cv2.imwrite(output_filename_2_region, binary_image_2_region)
    cv2.imwrite(output_filename_3_region, binary_image_3_region)
    cv2.imwrite(output_filename_4_region, binary_image_4_region)

    move_to_folder(output_filename_2_region)
    move_to_folder(output_filename_3_region)
    move_to_folder(output_filename_4_region)

    print(f"Results for {path}:")
    print("Optimal Threshold (2 regions):",
optimal_threshold_two_region)
    print("Optimal Thresholds (3 regions):",
optimal_threshold_three_region)
    print("Optimal Thresholds (4 regions):",
optimal_threshold_four_region)
    print("\n")
```

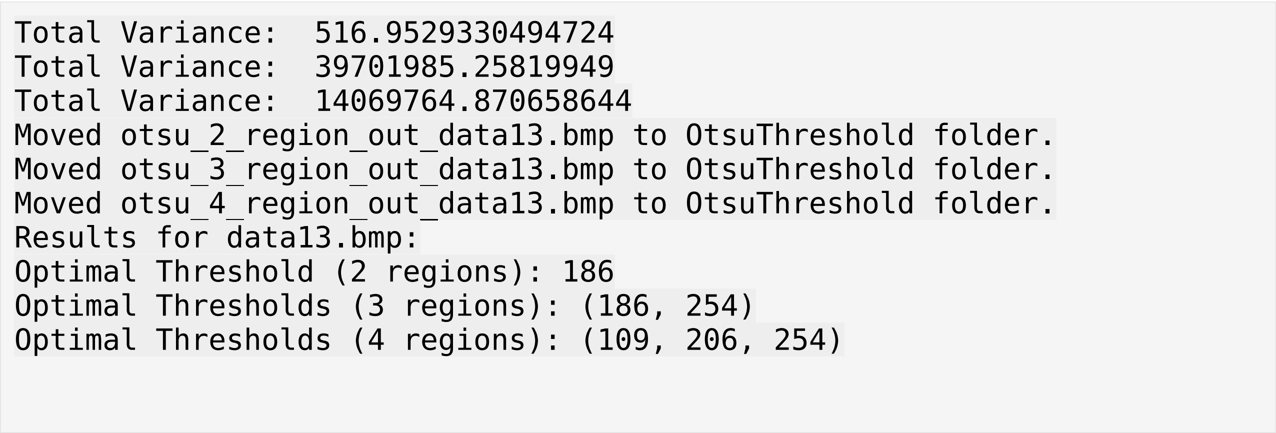


```
Total Variance:  1321.495701465642
Total Variance:  420354567.679206
Total Variance:  180965973.79668894
Moved otsu_2_region_out_tiger1.bmp to OtsuThreshold folder.
Moved otsu_3_region_out_tiger1.bmp to OtsuThreshold folder.
Moved otsu_4_region_out_tiger1.bmp to OtsuThreshold folder.
Results for tiger1.bmp:
Optimal Threshold (2 regions): 107
Optimal Thresholds (3 regions): (107, 254)
Optimal Thresholds (4 regions): (64, 151, 254)
```



```
Total Variance:  184.7546019457958
Total Variance:  266046626.80194592
Total Variance:  139525869.06259522
Moved otsu_2_region_out_basket_balls.bmp to OtsuThreshold folder.
Moved otsu_3_region_out_basket_balls.bmp to OtsuThreshold folder.
Moved otsu_4_region_out_basket_balls.bmp to OtsuThreshold folder.
Results for basket_balls.bmp:
Optimal Threshold (2 regions): 175
Optimal Thresholds (3 regions): (175, 254)
Optimal Thresholds (4 regions): (100, 184, 254)
```





```
Total Variance:  516.9529330494724
Total Variance:  39701985.25819949
Total Variance:  14069764.870658644
Moved otsu_2_region_out_data13.bmp to OtsuThreshold folder.
Moved otsu_3_region_out_data13.bmp to OtsuThreshold folder.
Moved otsu_4_region_out_data13.bmp to OtsuThreshold folder.
Results for data13.bmp:
Optimal Threshold (2 regions): 186
Optimal Thresholds (3 regions): (186, 254)
Optimal Thresholds (4 regions): (109, 206, 254)
```