Machine Problem 2

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Color Transformations

The goal of the machine problem is to apply the concepts of color transformations, specifically using histogram equalization and gamma correction techniques. You are to submit two files for this activity: (1) a Jupyter notebook containing the solutions to the action items. Ensure you provide comments, discussions, and proper section divisions for your code. Please also include your answer to the Guide Questions in the Jupyter Notebook; (2) a PDF version of your Jupyter Notebook. You can provide a link to your submission resources or a zip file. The instructor will run it on their local machine, so make sure the codes and files are accessible and functional.

In [1]:

```
import os
import cv2 as cv
import numpy as np
import matplotlib.pyplot as plt
import random
```

1. Information Extraction

1a. Reshape Images

Given the image dataset, reshape the images to (100,100,3).

1b. Saving resized images

Save the transformed images as JPEG files in a separate directory.

In [2]:

```
input_directory = '../media/dataset2'
output_directory = 'dataset2_resized'

if not os.path.exists(output_directory):
    os.makedirs(output_directory)

# Reshape images to (100, 100, 3)
for filename in os.listdir(input_directory):
    if filename.endswith('.png') or filename.endswith('.jpg'):
        img_path = os.path.join(input_directory, filename)
        img = cv.imread(img_path)

        # Resize the image to 100x100 pixels
        img_resized = cv.resize(img, (100, 100))

        # Save the resized image as JPEG in a separate directory
```

```
        output_filename = os.path.join(output_directory, filename)
        cv.imwrite(output_filename, img_resized)
```

1c. Color Channels Histogram

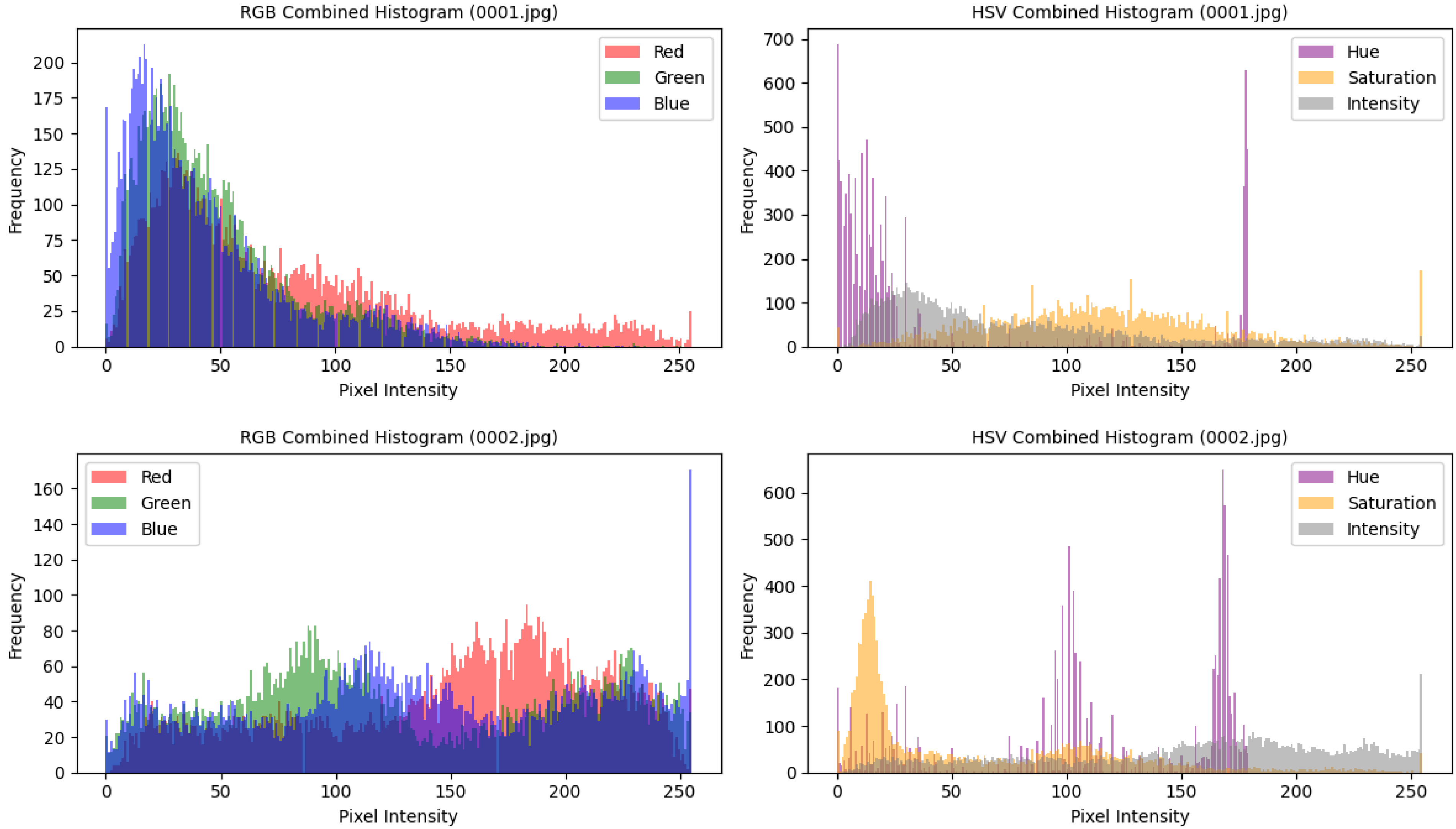
Create a histogram for the following channels: Reds, Greens, Blues, Hues, Saturations, Intensities

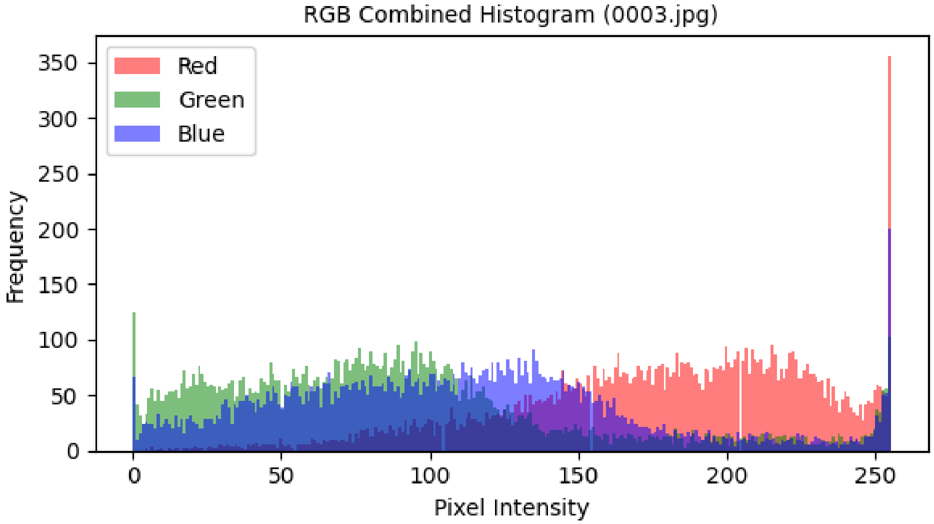
In [3]:

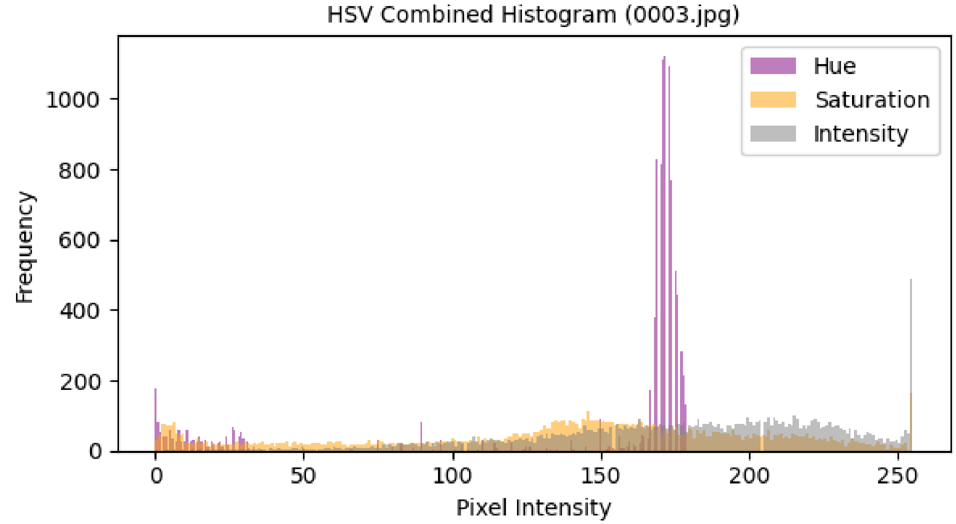
```
def plot_combined_histograms(img, img_name):
    # Split the channels for RGB
    b_channel, g_channel, r_channel = cv.split(img)

    # Convert the image to HSV for Hue, Saturation, and Intensity
    hsv_img = cv.cvtColor(img, cv.COLOR_BGR2HSV)
    h_channel, s_channel, v_channel = cv.split(hsv_img)

    # Create a figure with two subplots side by side for each image
    fig, axes = plt.subplots(1, 2, figsize=(12, 3.5))  # 1 row, 2 columns (side by side histograms)

    # Plot combined RGB histograms
    axes[0].hist(r_channel.ravel(), bins=256, color='red', alpha=0.5, label='Red')
    axes[0].hist(g_channel.ravel(), bins=256, color='green', alpha=0.5, label='Green')
    axes[0].hist(b_channel.ravel(), bins=256, color='blue', alpha=0.5, label='Blue')
    axes[0].set_title(f'RGB Combined Histogram ({img_name})',fontsize=10)
    axes[0].set_xlabel('Pixel Intensity')
    axes[0].set_ylabel('Frequency')
    axes[0].legend()

    r_channel.ravel()

    # Plot combined HSV histograms
    axes[1].hist(h_channel.ravel(), bins=256, color='purple', alpha=0.5, label='Hue')
    axes[1].hist(s_channel.ravel(), bins=256, color='orange', alpha=0.5, label='Saturation')
    axes[1].hist(v_channel.ravel(), bins=256, color='gray', alpha=0.5, label='Intensity')
    axes[1].set_title(f'HSV Combined Histogram ({img_name})', fontsize=10)
    axes[1].set_xlabel('Pixel Intensity')
    axes[1].set_ylabel('Frequency')
    axes[1].legend()

    # Adjust layout
    plt.tight_layout()
    plt.show()
```

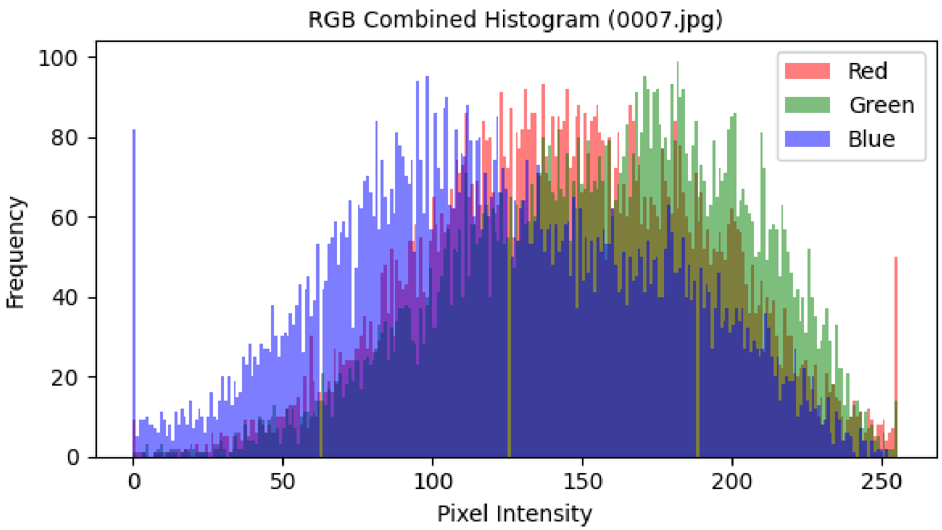
In [4]:

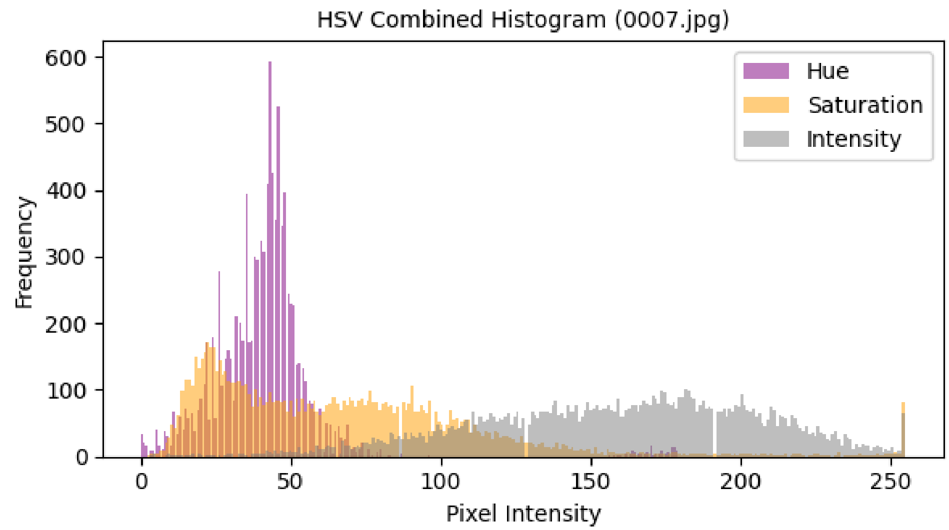
```
for filename in os.listdir(output_directory):
    if filename.endswith('.jpg'):
        img_path = os.path.join(output_directory, filename)
        img = cv.imread(img_path)

        plot_combined_histograms(img, filename)
```

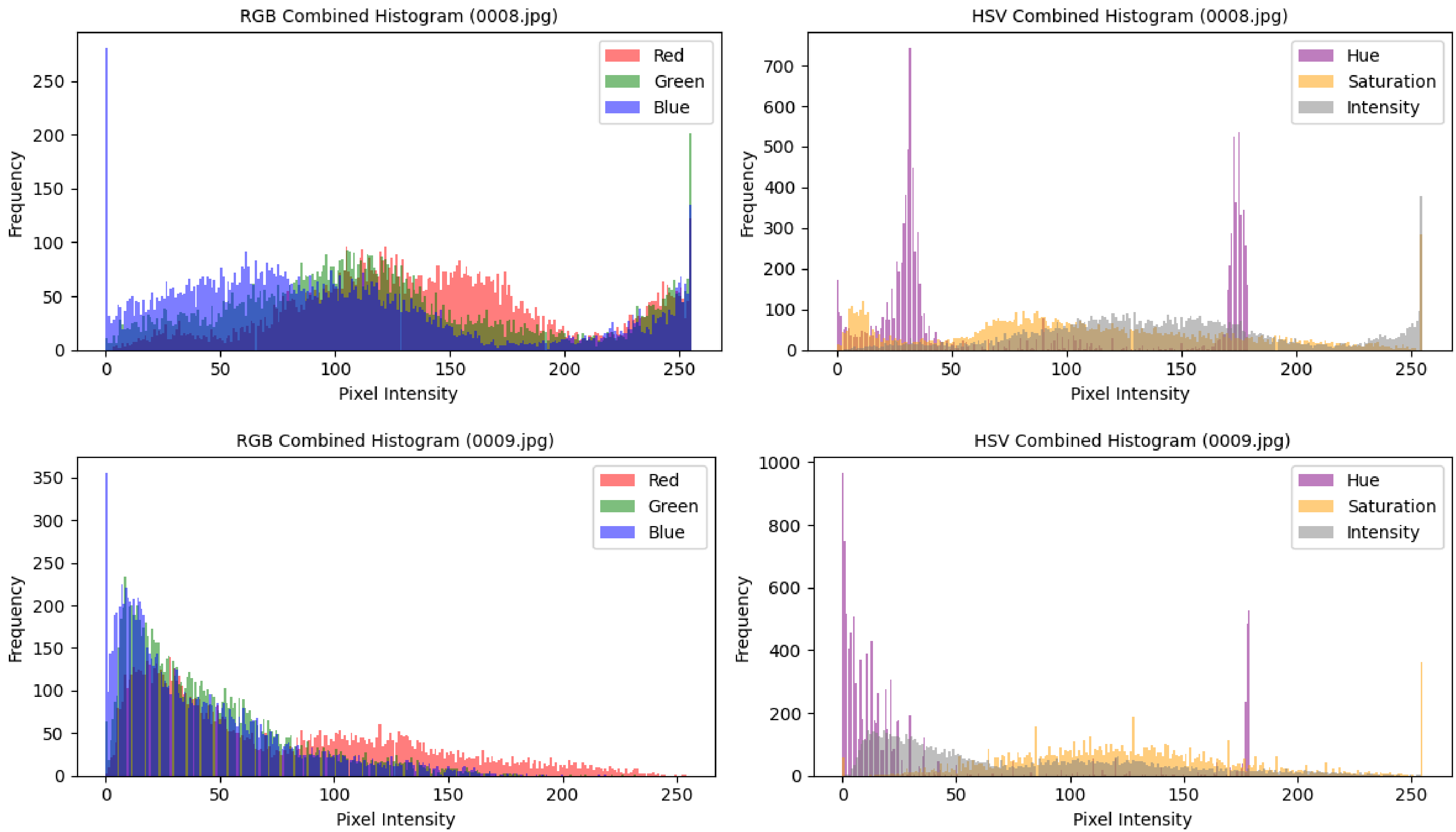

RGB Combined Histogram (0001.jpg)
Red
Green
Blue
Frequency
Pixel Intensity
HSV Combined Histogram (0001.jpg)
Hue
Saturation
Intensity
Frequency
Pixel Intensity
RGB Combined Histogram (0002.jpg)
Red
Green
Blue
Frequency
Pixel Intensity
HSV Combined Histogram (0002.jpg)
Hue
Saturation
Intensity
Frequency
Pixel Intensity

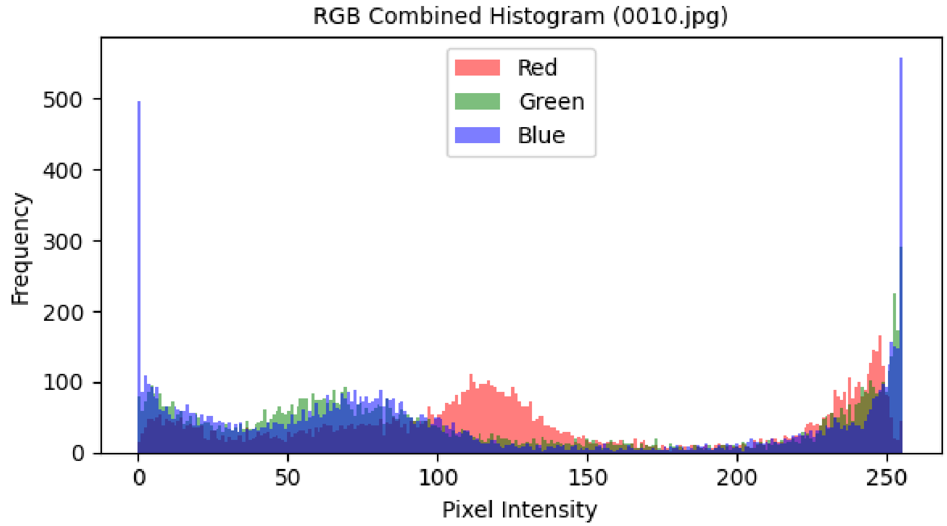

RGB Combined Histogram (0003.jpg)
Red
Green
Blue
Frequency
Pixel Intensity

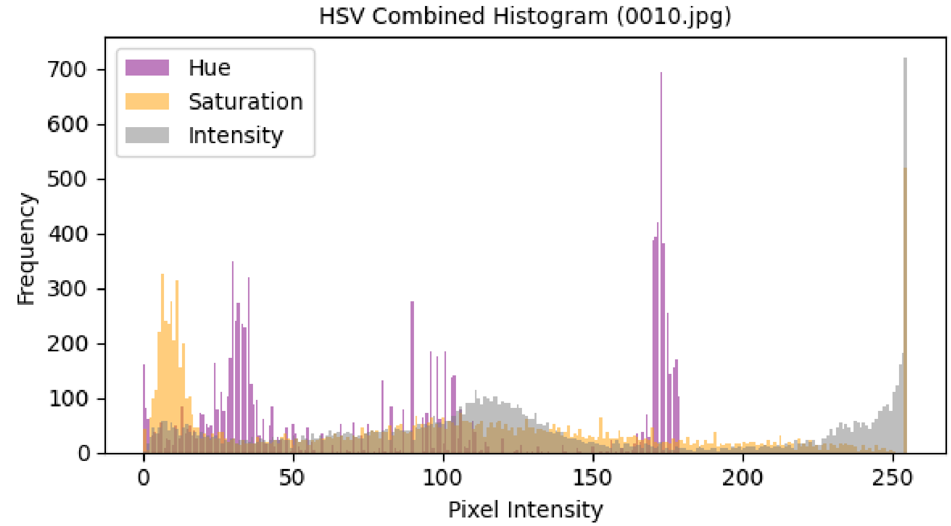

HSV Combined Histogram (0003.jpg)
Hue
Saturation
Intensity
Frequency
Pixel Intensity

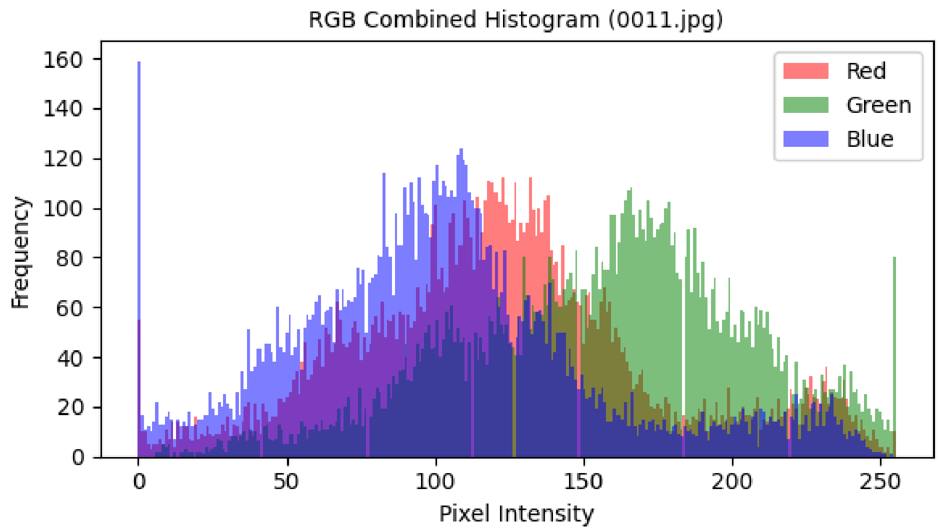

RGB Combined Histogram (0007.jpg)
Red
Green
Blue
Frequency
Pixel Intensity

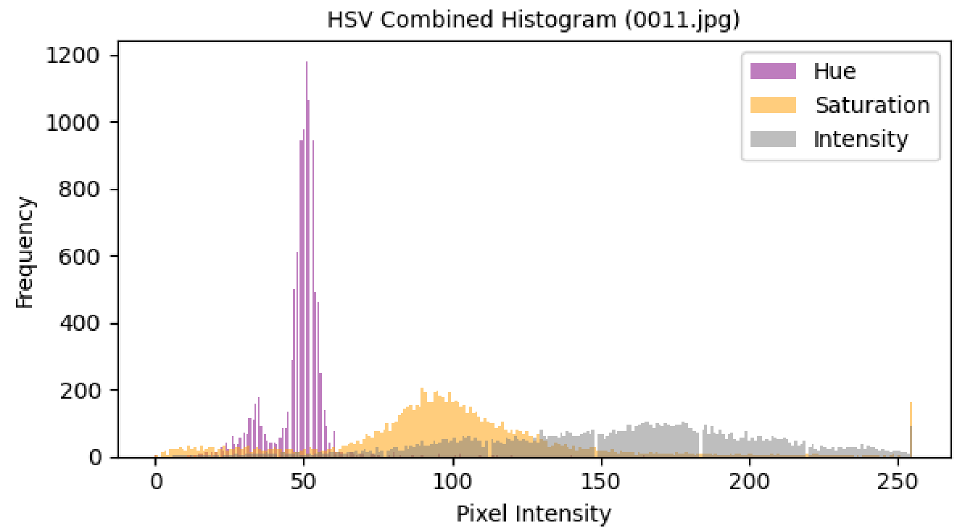

HSV Combined Histogram (0007.jpg)
Hue
Saturation
Intensity
Frequency
Pixel Intensity

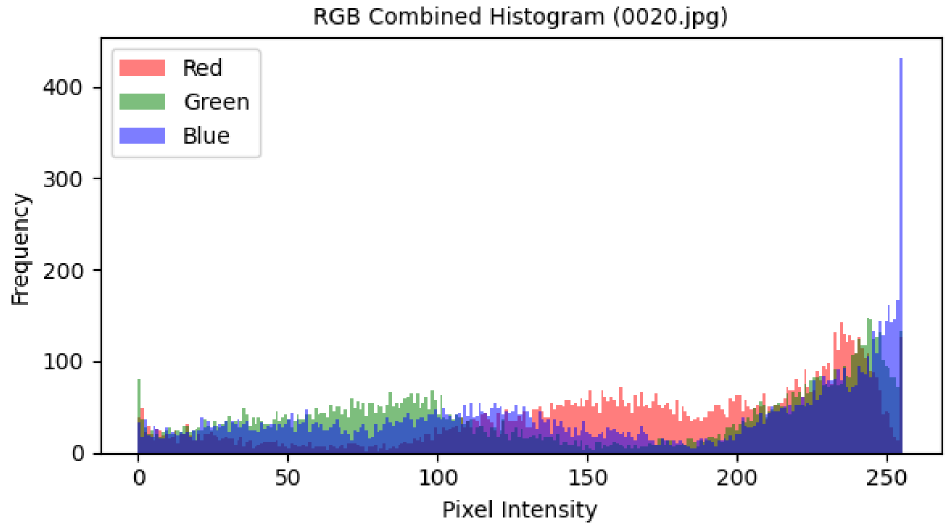

RGB Combined Histogram (0008.jpg)
Red
Green
Blue
Frequency
Pixel Intensity
HSV Combined Histogram (0008.jpg)
Hue
Saturation
Intensity
Frequency
Pixel Intensity
RGB Combined Histogram (0009.jpg)
Red
Green
Blue
Frequency
Pixel Intensity
HSV Combined Histogram (0009.jpg)
Hue
Saturation
Intensity
Frequency
Pixel Intensity

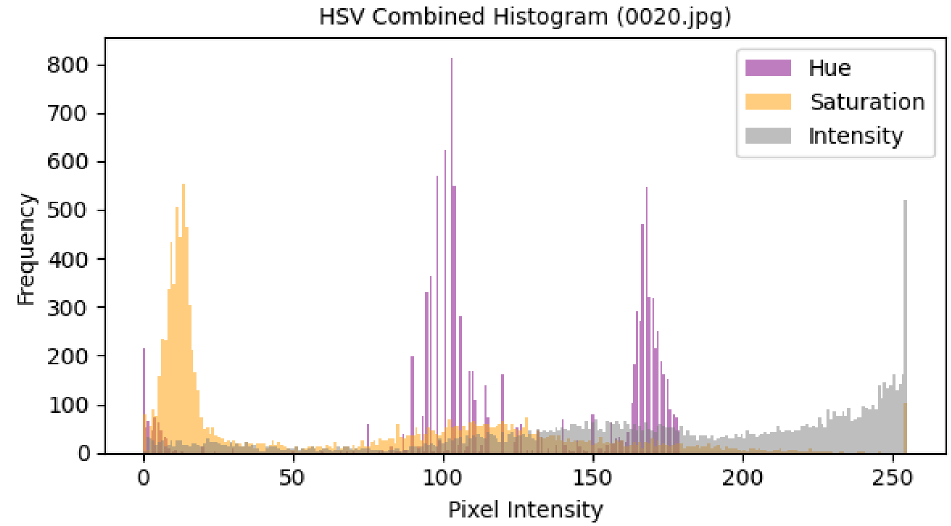

RGB Combined Histogram (0010.jpg)
Red
Green
Blue
Frequency
Pixel Intensity

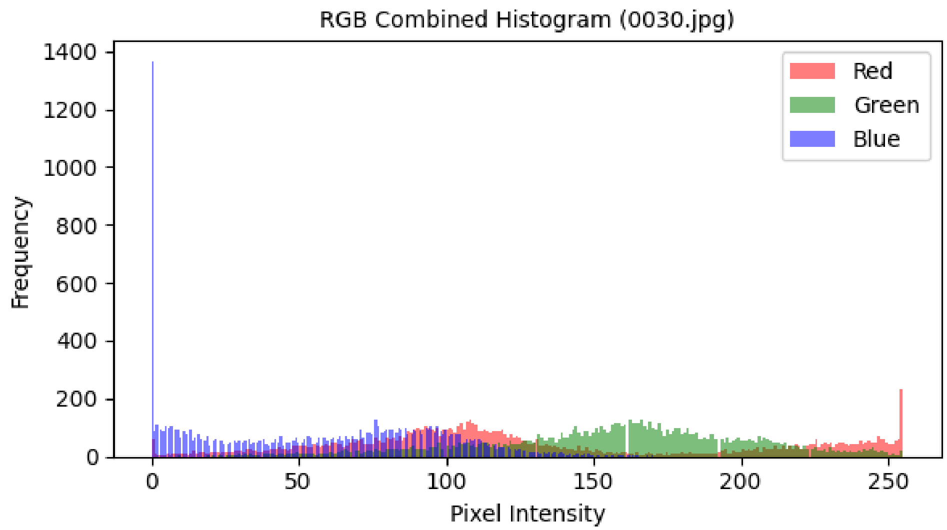

HSV Combined Histogram (0010.jpg)
Hue
Saturation
Intensity
Frequency
Pixel Intensity

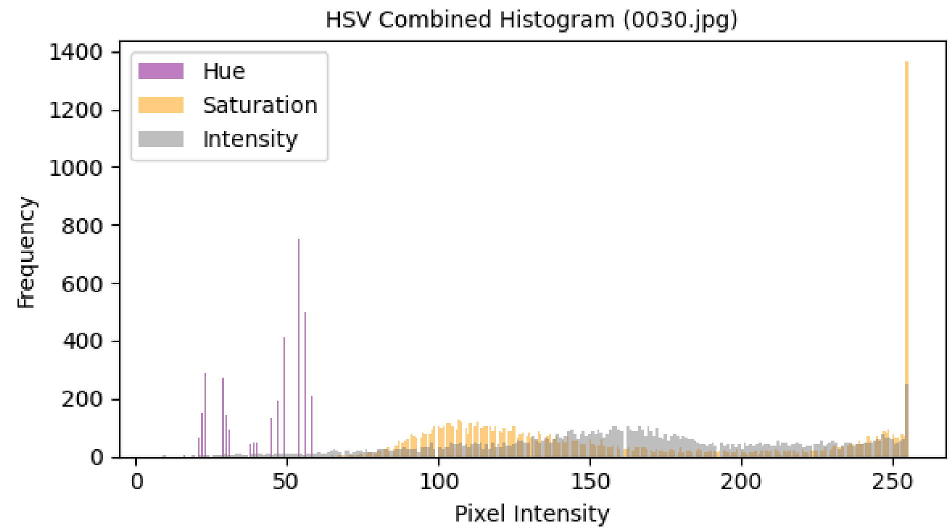

RGB Combined Histogram (0011.jpg)
Red
Green
Blue
Frequency
Pixel Intensity


HSV Combined Histogram (0011.jpg)
Hue
Saturation
Intensity
Frequency
Pixel Intensity









1d. Guide Questions

1. In the RGB space, which channel is most likely to be observed for all images?

Blue is the channel most frequently observed across all the images. In almost all of the RGB histograms, the blue channel has a strong peak near 0 intensity (darker values) and another significant peak near 255 (brighter values), indicating its dominance.

2. In the HSV space, which top three hues are most likely to be observed for all images?

The top three most observed hues across the images, based on the histograms for hue, appear to be concentrated around:

- 0 to 50 (Reddish tones)
- 100 to 150 (Greenish to yellowish tones)

- 150 to 200 (Bluish tones)

2. Data Cleaning

Develop a function that attains the following activities:

- Remove all images that are taken during the night.
- Remove all images that are not pink flowers.

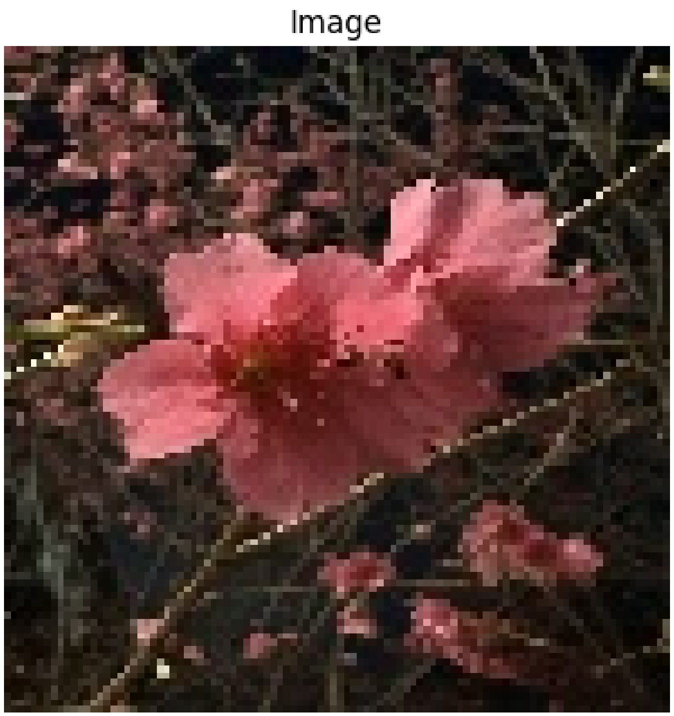
In [5]:
```
# Function to display an image
def display_image(image, title="Image"):
    img_rgb = cv.cvtColor(image, cv.COLOR_BGR2RGB)
    plt.imshow(img_rgb)
    plt.title(title)
    plt.axis('off')
    plt.show()
```

2a. Removing images taken during the night

In [6]:
```
input_directory = 'dataset2_resized'
output_directory = 'non_night_images'

def is_night_image(image, dark_pixel_percentage_threshold=0.5):
    # Convert the image to grayscale to analyze pixel values
    gray_image = cv.cvtColor(image, cv.COLOR_BGR2GRAY)

    # Compute the histogram
    histogram, _ = np.histogram(gray_image, bins=256, range=(0, 256))

    # Calculate the total number of pixels
    total_pixels = gray_image.size

    # Calculate the number of dark pixels (e.g., pixel value < 50)
    dark_pixel_count = np.sum(histogram[:50])  # Sum the counts of dark pixels
    dark_pixel_percentage = dark_pixel_count / total_pixels

    # Determine if the image is taken at night
    return dark_pixel_percentage > dark_pixel_percentage_threshold

def save_non_night_images(input_directory, output_directory):
    # Create the output directory if it doesn't exist
    if not os.path.exists(output_directory):
        os.makedirs(output_directory)

    for filename in os.listdir(input_directory):
        if filename.endswith('.jpg'):
            img_path = os.path.join(input_directory, filename)
            img = cv.imread(img_path)
```

```python
            if img is None:
                print(f"Error: Unable to load {img_path}")
                continue

            # Check if the image is taken during the night
            if not is_night_image(img):
                output_path = os.path.join(output_directory, filename)
                cv.imwrite(output_path, img)  # Save the non-night image
            else:
                print(f"Skipping night image: {filename}")
                display_image(img)

save_non_night_images(input_directory, output_directory)
```

```
Skipping night image: 0001.jpg
```




```
Skipping night image: 0009.jpg
```

Image

2b. Removing images of non-pink flowers

In [7]:
```
input_directory = 'dataset2_resized'
output_directory = 'pink_flower_images'

def is_pink_flower(image, lower_hue=160, upper_hue=180, saturation_threshold=50, value_threshold=50):
    # Convert the image to HSV color space
    hsv_image = cv.cvtColor(image, cv.COLOR_BGR2HSV)

    # Create a mask for pink color (using defined HSV range)
    lower_color = np.array([lower_hue, saturation_threshold, value_threshold])
    upper_color = np.array([upper_hue, 255, 255])

    # Generate mask
    mask = cv.inRange(hsv_image, lower_color, upper_color)

    # Calculate the percentage of pink pixels
    pink_pixel_count = np.sum(mask > 0)
    total_pixel_count = mask.size  # Total number of pixels

    # Calculate the percentage of pink pixels in the image
    pink_pixel_percentage = pink_pixel_count / total_pixel_count

    return pink_pixel_percentage > 0.1  # Adjust the threshold as needed

# Function to save pink flower images and display non-pink images
def save_pink_flower_images(input_directory, output_directory):
```

```
    # Create the output directory if it doesn't exist
    if not os.path.exists(output_directory):
        os.makedirs(output_directory)

    for filename in os.listdir(input_directory):
        if filename.endswith('.jpg'):
            img_path = os.path.join(input_directory, filename)
            img = cv.imread(img_path)

            if img is None:
                print(f"Error: Unable to load {img_path}")
                continue

            # Check if the image contains pink flowers
            if is_pink_flower(img):
                output_path = os.path.join(output_directory, filename)
                cv.imwrite(output_path, img)  # Save the pink flower image
            else:
                print(f"Displaying non-pink flower image: {filename}")
                display_image(img, title=f"Non-Pink Image: {filename}")


save_pink_flower_images(input_directory, output_directory)
```

```
Displaying non-pink flower image: 0007.jpg
```


```
Displaying non-pink flower image: 0011.jpg
```

Non-Pink Image: 0011.jpg

Displaying non-pink flower image: 0030.jpg

Non-Pink Image: 0030.jpg

2c. Guide Questions

1. What mathematical or statistical bases have you considered when developing your function?

The functions for detecting night images and removing non-pink flower images utilize several mathematical and statistical concepts centered around histogram and color space analysis. The night image detection function constructs a histogram of pixel intensity values from the grayscale version of an image, allowing for the quantification of dark pixels by summing those below a specified threshold (e.g., 50). The dark pixel percentage is calculated by dividing the dark pixel count by the total number of pixels, which is then compared against a user-defined threshold (e.g., `dark_pixel_percentage_threshold`) to classify the image as night or non-night. In contrast, the function for removing non-pink flower images converts images from BGR to HSV color space to isolate specific colors more intuitively. It generates a mask based on defined lower and upper hue thresholds to capture pixels within the pink color range, calculating the percentage of pink pixels by dividing the count of pink pixels by the total pixel count. This percentage is then compared against a predetermined threshold (e.g., 10%) to determine whether the image contains a sufficient proportion of pink flowers. By applying these techniques, both functions effectively filter images based on pixel intensity distributions and color content, ensuring that only relevant images are retained for further use.

2. What are the challenges in re-orienting the images in this action item?

Re-orienting images poses several challenges, primarily related to orientation detection and processing consistency. Accurately determining an image's orientation can be complex, as different images may have varying degrees of rotation or tilt, necessitating robust algorithms. Reliance on EXIF metadata for orientation can be problematic if it's missing or incorrect, and maintaining or updating this metadata during rotation is essential. Consistency in processing is crucial, as variability in image sources can lead to inconsistencies in output. Additionally, rotating images may introduce artifacts that affect quality, particularly in high-fidelity applications. Performance considerations are also significant for large datasets, requiring efficient algorithms to avoid delays. Edge cases, such as abstract images with minimal distinct features, can complicate detection, and complex backgrounds may hinder accurate orientation. Addressing these challenges requires a combination of advanced algorithms, careful metadata handling, and a focus on maintaining quality and efficiency.

3. What can you suggest for automating such a task?

To automate the tasks of re-orienting images and filtering out non-pink flower images while detecting night images, a structured approach can be taken. First, leveraging image processing libraries like OpenCV or PIL is essential for efficient image manipulation. Developing algorithms that detect image orientation using feature detection methods or machine learning models trained on specific datasets can enhance accuracy.

For efficiency, implementing batch processing to handle multiple images simultaneously will significantly speed up the workflow. Additionally, creating scripts to read and update EXIF metadata ensures that orientation information remains accurate. Utilizing parallel processing frameworks can further improve performance, especially when dealing with large volumes of images.

Incorporating a calibration phase allows for fine-tuning parameters related to detecting pink flowers and dark pixels, which is crucial for achieving reliable results. Including logging will help monitor the process, while establishing a user feedback loop can validate any necessary orientation corrections.

Then, integrating the automation into a larger data processing pipeline using tools like Apache Airflow can enhance workflow management. Implementing automated quality control checks will also ensure the accuracy of the outputs. Combining these strategies will lead to a more efficient and effective image processing system.

3. Data Enhancement

From the cleaned dataset, develop and apply a function that:

- Adjusts the exposure of the images based on the brightest image. *(Hint: You may manually select the representative image and apply Gamma Correction)*

- Adjusts the saturation of the images to match the saturation of the most saturated image. *(Hint: You may manually select the representative image and apply Histogram Equalization and Channel Arithmetic)*

3a. Adjust exposure

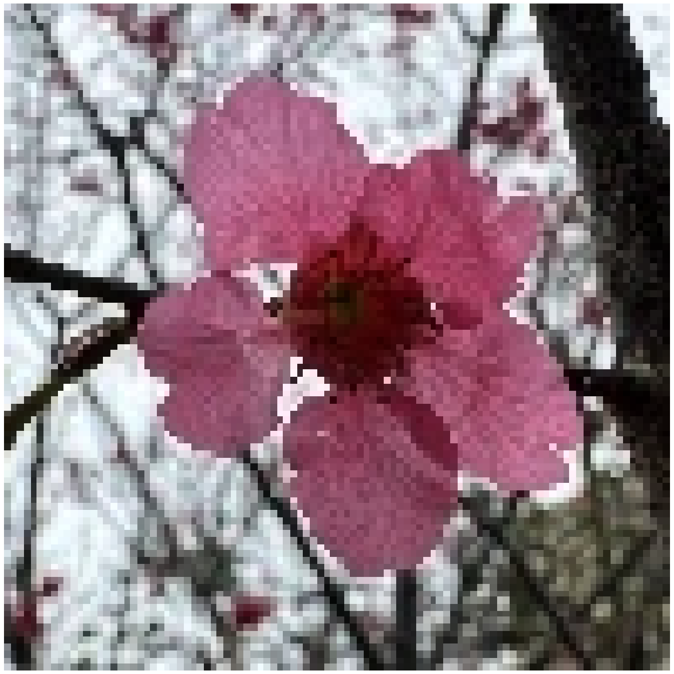
In [8]:
```python
def find_brightest_image(output_directory):

    brightest_image_name = None
    max_brightness = -1  # initialize

    for filename in os.listdir(output_directory):
        if filename.endswith('.jpg'):
            img_path = os.path.join(output_directory, filename)
            img = cv.imread(img_path)

            # calculate average brightness
            gray_image = cv.cvtColor(img, cv.COLOR_BGR2GRAY)
            brightness = np.mean(gray_image)

            # update when found
            if brightness > max_brightness:
                max_brightness = brightness
                brightest_image_name = filename

    return brightest_image_name

def adjust_exposure(output_directory):

    bright_image_name = find_brightest_image(output_directory)
    bright_image_path = os.path.join(output_directory, bright_image_name)

    # calculate average brightness
    bright_image = cv.imread(bright_image_path)
    bright_gray = cv.cvtColor(bright_image, cv.COLOR_BGR2GRAY)
    bright_brightness = np.mean(bright_gray)
    target_brightness = bright_brightness

    # adjust exposure based on the brightest image
    for filename in os.listdir(output_directory):
        if filename.endswith('.jpg'):
            img_path = os.path.join(output_directory, filename)
            img = cv.imread(img_path)

            # calculate the brightness and gamma of each image
            gray_image = cv.cvtColor(img, cv.COLOR_BGR2GRAY)
            current_brightness = np.mean(gray_image)
            gamma = current_brightness / target_brightness

            # clamp the gamma value to avoid over-darkening or over-brightening
            gamma = max(0.5, min(gamma, 2.0))
```

```
            # gamma correction
            inv_gamma = 1.0 / gamma
            table = np.array([((i / 255.0) ** inv_gamma) * 255 for i in np.arange(0, 256)]).astype("uint8")
            adjusted_image = cv.LUT(img, table)

            # display
            print(f"Displaying image: {filename}")
            display_image(adjusted_image, title=f"Adjusted Image: {filename}")

adjust_exposure(output_directory)
```

```
Displaying image: 0001.jpg
```


```
Displaying image: 0002.jpg
```

Adjusted Image: 0002.jpg



Displaying image: 0003.jpg

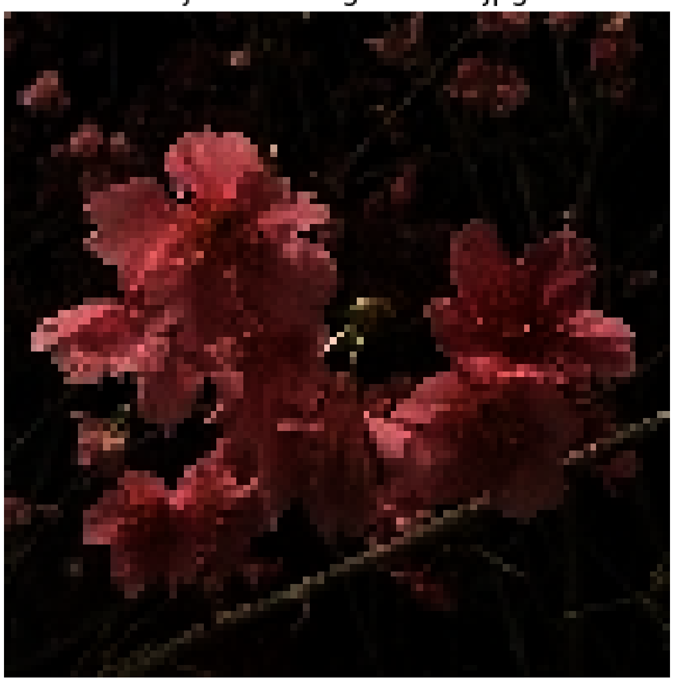
Adjusted Image: 0003.jpg

Displaying image: 0008.jpg

Adjusted Image: 0008.jpg

Displaying image: 0009.jpg

Adjusted Image: 0009.jpg

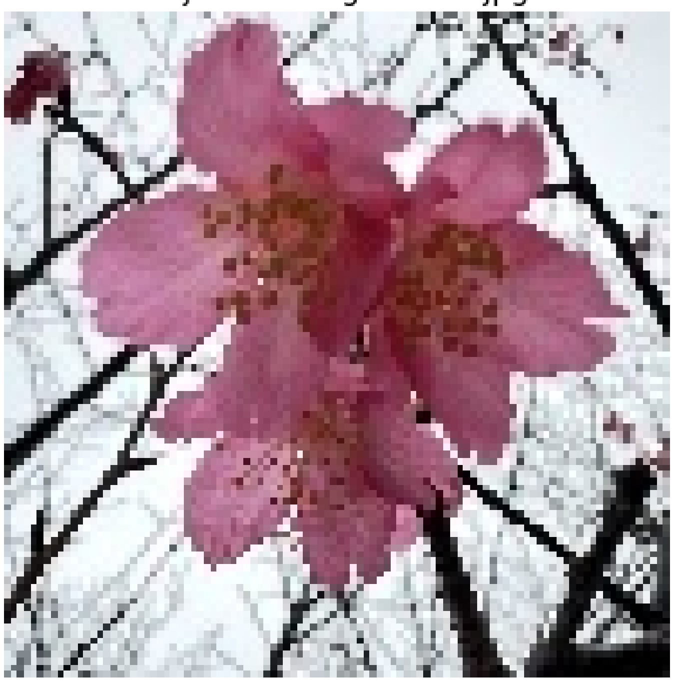


Displaying image: 0010.jpg

Adjusted Image: 0010.jpg

```
Displaying image: 0020.jpg
```

Adjusted Image: 0020.jpg



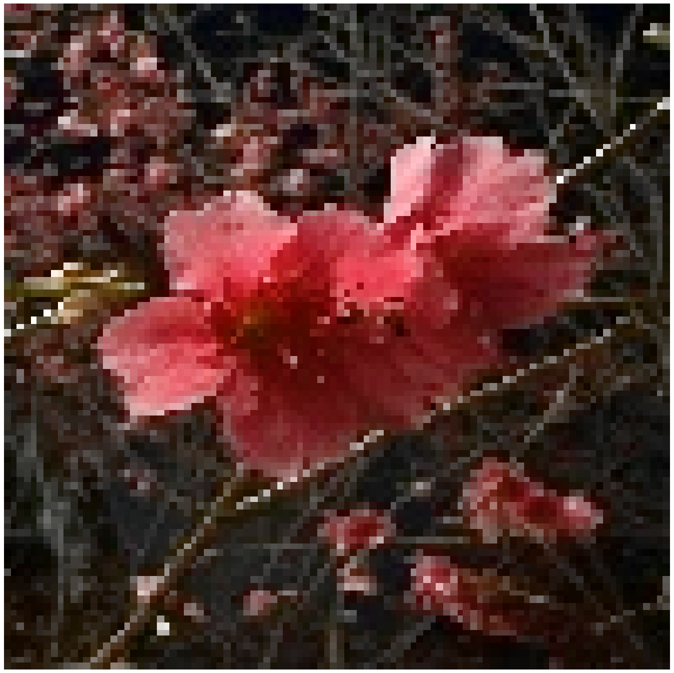
3b. Adjust saturation

In [9]:
```python
def adjust_saturation(output_directory):

    most_saturated_image_name = find_most_saturated_image(output_directory)
    most_saturated_image_path = os.path.join(output_directory, most_saturated_image_name)

    # calculate average saturation
    most_saturated_image = cv.imread(most_saturated_image_path)
    hsv_image = cv.cvtColor(most_saturated_image, cv.COLOR_BGR2HSV)
    most_saturated_value = np.mean(hsv_image[:, :, 1])
    target_saturation = most_saturated_value

    for filename in os.listdir(output_directory):
        if filename.endswith('.jpg'):
            img_path = os.path.join(output_directory, filename)
            img = cv.imread(img_path)

            hsv_img = cv.cvtColor(img, cv.COLOR_BGR2HSV)
            current_saturation = np.mean(hsv_img[:, :, 1])

            scaling_factor = target_saturation / current_saturation

            # adjust the saturation by multiplying the scaling factor
            hsv_img[:, :, 1] = np.clip(hsv_img[:, :, 1] * scaling_factor, 0, 255)

            # apply histogram equalization to enhance saturation contrast
            hsv_img[:, :, 1] = cv.equalizeHist(hsv_img[:, :, 1])

            # convert back after saturation adjustment
            adjusted_img = cv.cvtColor(hsv_img, cv.COLOR_HSV2BGR)

            print(f"Displaying image: {filename}")
            display_image(adjusted_img, title=f"Adjusted Image: {filename}")

def find_most_saturated_image(output_directory):
    most_saturated_image_name = None
    max_saturation = -1  # initialize

    for filename in os.listdir(output_directory):
        if filename.endswith('.jpg'):
            img_path = os.path.join(output_directory, filename)
            img = cv.imread(img_path)

            # convert image to HSV and calculate average saturation
            hsv_img = cv.cvtColor(img, cv.COLOR_BGR2HSV)
            avg_saturation = np.mean(hsv_img[:, :, 1])

            # update when most saturated is found
            if avg_saturation > max_saturation:
                max_saturation = avg_saturation
                most_saturated_image_name = filename

    return most_saturated_image_name
```

```
adjust_saturation(output_directory)
```

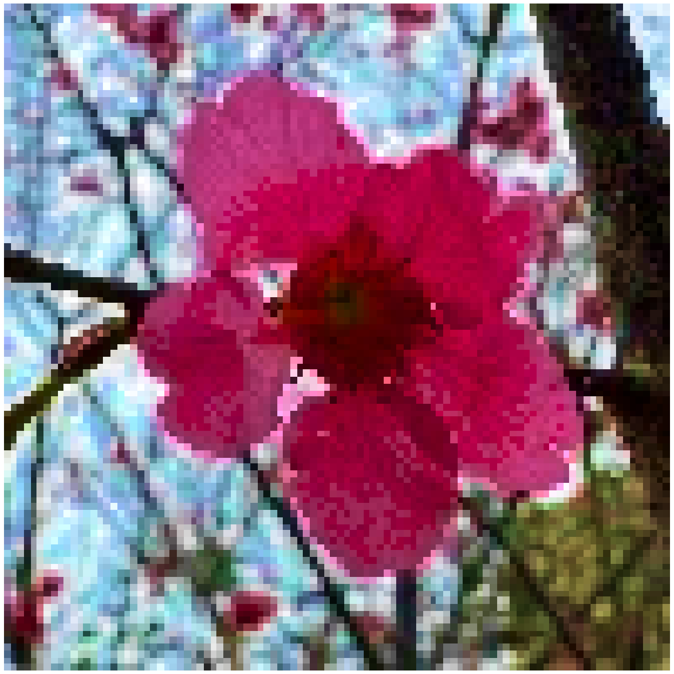
```
Displaying image: 0001.jpg
```

Adjusted Image: 0001.jpg



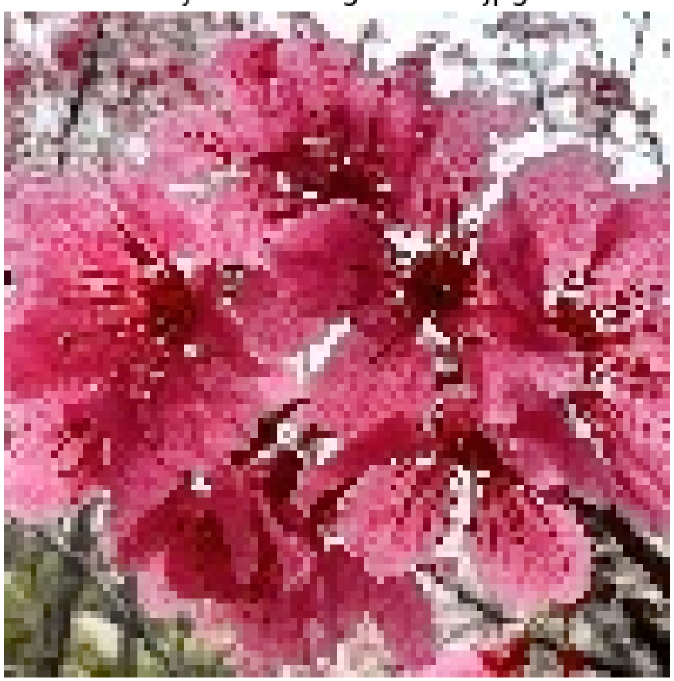
```
Displaying image: 0002.jpg
```

Adjusted Image: 0002.jpg



```
Displaying image: 0003.jpg
```

Adjusted Image: 0003.jpg

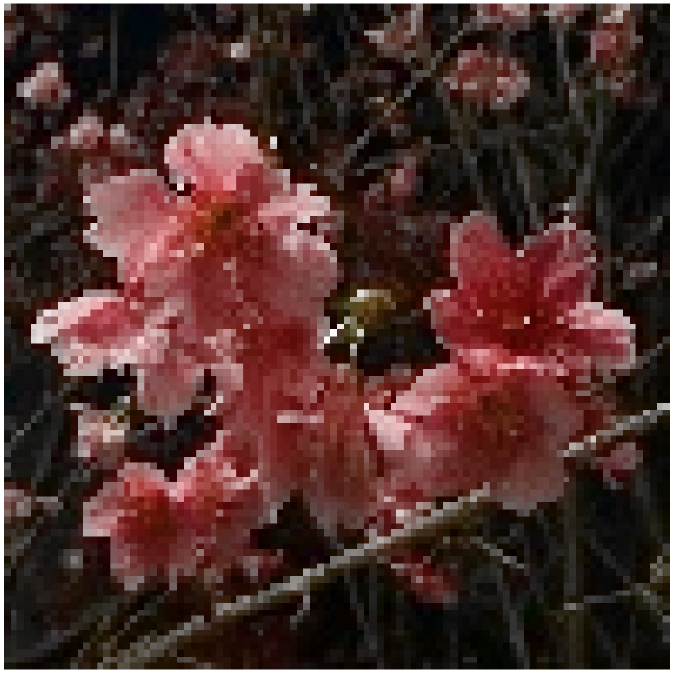


```
Displaying image: 0008.jpg
```

Adjusted Image: 0008.jpg

```
Displaying image: 0009.jpg
```

Adjusted Image: 0009.jpg

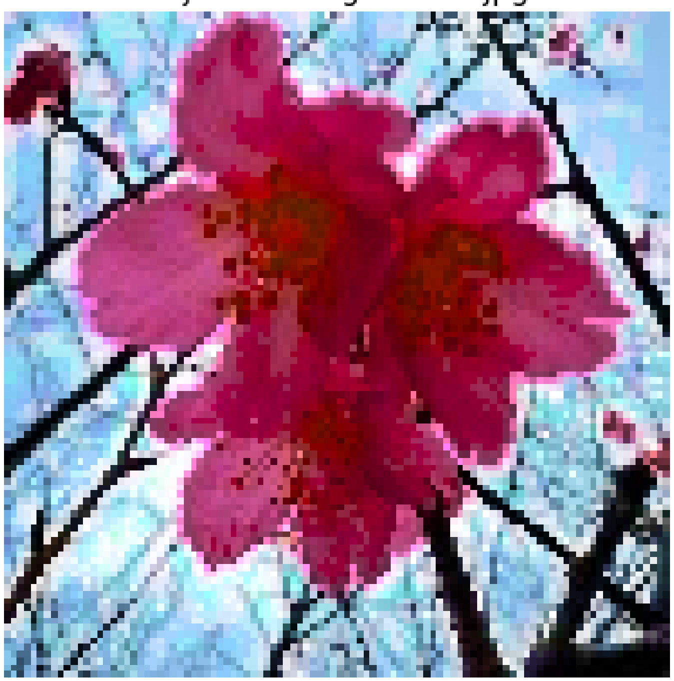


```
Displaying image: 0010.jpg
```

Adjusted Image: 0010.jpg

Displaying image: 0020.jpg

Adjusted Image: 0020.jpg



4. Modified Data Augmentation

Reuse the data augmentation functions from MP2 on geometric transformations and add the following augmentation techniques:

- Increase or decrease the saturation.

Reused data augmentation functions from MP1

- Randomly put a black patch over a portion of the image

In [10]:
```
def random_black_patch(img):
    h, w, _ = img.shape
    patch_size = np.random.randint(10, 30) # randomly selects the size of the black patch, currently set between 10 to 30 pixels
    x1 = np.random.randint(0, w - patch_size)
    y1 = np.random.randint(0, h - patch_size)
    img[y1:y1+patch_size, x1:x1+patch_size] = 0 # sets the pixels in the selected area to black
    return img
```

- Shift an image sideward or upwards

In [11]:
```
def shift_image(img, shift_x, shift_y):
    h, w = img.shape[:2]

    # creates a transformation matrix for shifting
    # [1, 0, shift_x] shifts the image by 'shift_x' pixels horizontally
    # [0, 1, shift_y] shifts the image by 'shift_y' pixels vertically
    M = np.float32([[1, 0, shift_x], [0, 1, shift_y]])
    shifted_img = cv.warpAffine(img, M, (w, h)) # apply the shifting using the affine transformation
    return shifted_img
```

- Rotate an image either for

In [12]:
```
def rotate_image(img, angle):
    h, w = img.shape[:2]
    center = (w // 2, h // 2) # determines the center of the image
    M = cv.getRotationMatrix2D(center, angle, 1.0) # positive angle -> counter clockwise rotation, negative angle -> clockwise rotation
    rotated_img = cv.warpAffine(img, M, (w, h)) # apply the rotation using the affine transformation
    return rotated_img
```

- Flip an image either vertically or horizontally

In [13]:
```
def flip_image(image, value):
    return cv.flip(image, value)  # 0 -> vertical, 1 -> horizontal
```

4a. Adjusting saturation

In [14]:
```python
def adjust_saturation(img, saturation_scale=1.0):
    # Convert BGR to HSV
    hsv_img = cv.cvtColor(img, cv.COLOR_BGR2HSV)

    # Scale the saturation channel (S)
    hsv_img[:, :, 1] = np.clip(hsv_img[:, :, 1] * saturation_scale, 0, 255)

    # Convert back to BGR
    img_with_adjusted_saturation = cv.cvtColor(hsv_img, cv.COLOR_HSV2BGR)
    return img_with_adjusted_saturation
```

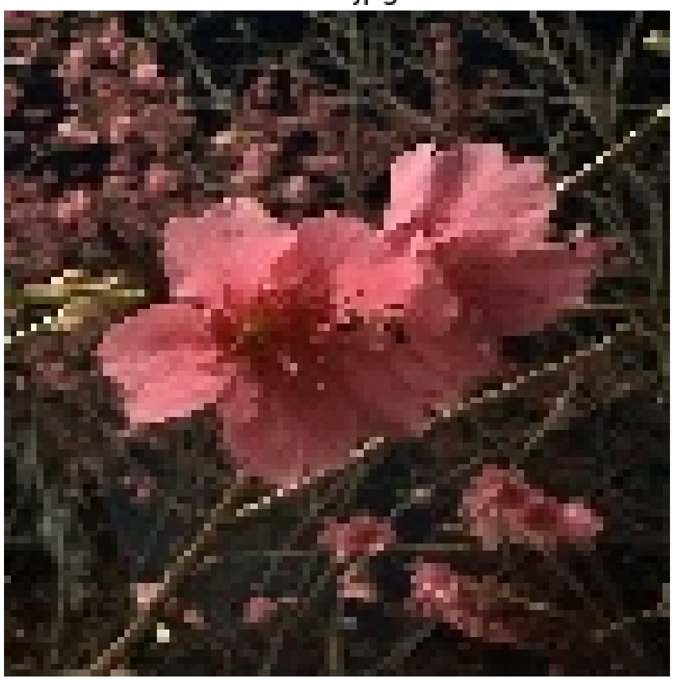
In [15]:
```python
def combine_augmentations(image, aug_func1, aug_func2):
    # Apply the first augmentation
    img_aug1 = aug_func1(image.copy())
    # Apply the second augmentation
    img_aug2 = aug_func2(img_aug1)
    return img_aug2

input_directory = 'dataset2_resized'
augmented_output_dir = 'modified_dataset2_augmented'
if not os.path.exists(augmented_output_dir): # creates directory if does not exist
    os.makedirs(augmented_output_dir)

image_count = 0
augmentations = [
    (random_black_patch, 'random_black_patch'),
    (lambda img: shift_image(img, 20, 0), 'shift_right_20px'),
    (lambda img: shift_image(img, 0, -20), 'shift_up_20px'),
    (lambda img: rotate_image(img, 45), 'rotate_45_degrees'),
    (lambda img: flip_image(img, 0), 'flip_vertically'),
    (lambda img: flip_image(img, 1), 'flip_horizontally'),
    (lambda img: adjust_saturation(img, 1.5), 'increase_saturation_1.5'),
    (lambda img: adjust_saturation(img, 0.5), 'decrease_saturation_0.5'),
]

for filename in os.listdir(input_directory):
    if filename.endswith('.jpg'):
        img_path = os.path.join(input_directory, filename)
        image = cv.imread(img_path)

        # Save the original resized image
        cv.imwrite(os.path.join(augmented_output_dir, filename), image)
        image_count += 1

        # Save the augmented images (single and combined)
        for i in range(len(augmentations)):
            # Single augmentations
            aug_func, aug_desc = augmentations[i]
            output_filename = f'{filename.split(".")[0]}_{aug_desc}.jpg'
            cv.imwrite(os.path.join(augmented_output_dir, output_filename), aug_func(image.copy()))
            image_count += 1
```

```python
            # Combine augmentations
            for j in range(i + 1, len(augmentations)):
                aug_func2, aug_desc2 = augmentations[j]
                combined_image = combine_augmentations(image, aug_func, aug_func2)
                output_filename_combined = f'{filename.split(".")[0]}_{aug_desc}_{aug_desc2}.jpg'
                cv.imwrite(os.path.join(augmented_output_dir, output_filename_combined), combined_image)
                image_count += 1

            if image_count >= 370:
                break

    if image_count >= 370:
        break
```

Sample Output

In [16]:
```python
image_files = os.listdir(augmented_output_dir)

image_files = [f for f in image_files if f.endswith('.jpg')]

for i in range(min(5, len(image_files))):
    img_path = os.path.join(augmented_output_dir, image_files[i])
    image = cv.imread(img_path)
    display_image(image, title=image_files[i])
```

0001.jpg



0001_decrease_saturation_0.5.jpg

0001_flip_horizontally.jpg

0001_flip_horizontally_decrease_saturation_0.5.jpg

0001_flip_horizontally_increase_saturation_1.5.jpg