**Assignment 2: Enhanced Image Processing Toolkit**

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**1. Introduction**

This report outlines the advancements made in image processing techniques as part of HW-2. Building upon the foundational skills developed in the previous assignment, this project delves into more sophisticated methods of image augmentation, focusing on histogram modification and color processing. The primary objective is to explore the effects of these techniques on both grayscale and color images, enhancing their quality and preparing them for further analysis or application. Through the implementation of global and local histogram stretching, sliding window histogram processing, and targeted color channel adjustments, we aim to demonstrate the versatility and impact of these image processing tools in transforming and augmenting digital images.

**2. Implementation and Algorithm Concepts**

This project focuses on enhancing image quality through histogram and color processing. Key techniques include:

**Histogram Stretching**

* Purpose: Enhances image contrast by expanding the range of intensity values.
* Method: Maps original intensity values to a new specified range, with thresholds to ensure extreme values are capped.

**Local Histogram Stretching**

* Purpose: Provides localized contrast enhancement by dividing the image into smaller regions and applying histogram stretching individually.
* Method: The target area is segmented, histogram stretching is applied to each segment, and the segments are recombined.

**Sliding Window Processing**

* Purpose: Addresses non-uniform lighting by adapting to local intensity variations.
* Method: A moving window iterates over the image, applying histogram stretching based on the local histogram within the window.

**Color Channel Modifications**

* Purpose: Alters the image's color balance and appearance by adjusting individual color channels.
* Method: The image is split into RGB channels, modifications are applied to selected channels, and the channels are merged back.

These techniques enable significant improvements in image clarity, contrast, and color balance, making them fundamental for image preprocessing and analysis.

**3. Results with Parameters**

**3.1 Global Histogram Stretching**

The implementation of global histogram stretching aimed to enhance the contrast of grayscale images by adjusting their intensity ranges. This technique is particularly effective in images with a narrow range of intensity values, making them appear flat and lacking in detail.

For the baboon.png image, histogram stretching was applied with user-defined parameters A=50 and B=235. These parameters determined the new intensity range of the stretched histogram. The stretching operation remapped the intensities in the original image range ([c, d]) to the new range ([A, B]), where c is set to 1.05 times the minimum intensity value (I-min) in the original image, and d is set to 0.95 times the maximum intensity value (I-max). Intensities below 1.05I-min were mapped to A, and intensities above 0.95I-max were mapped to B, effectively expanding the contrast of the image.

Figure 1 provides a side-by-side comparison of the original baboon.png image and the result of applying histogram stretching. The enhanced image exhibits improved contrast, with previously indistinct features becoming more pronounced.

**Figure 1**

**Close-up of a baboon's face

Description automatically generated** **Close-up of a baboon's face

Description automatically generated**

Figure 2 showcases the histograms before and after applying the histogram stretching function. The "before" histogram displays a concentration of intensity values within a narrow range, while the "after" histogram demonstrates a broader distribution of intensities across the new range [A, B], confirming the successful expansion of contrast in the image.

**Figure 2**

**A graph of a graph

Description automatically generated with medium confidence** **A black and white graph

Description automatically generated**

This method proved effective in enhancing the visual clarity of the grayscale image by stretching its intensity distribution to utilize a wider range of values, thereby improving contrast, and revealing hidden details.

**3.2 Local Histogram Stretching**

Building upon the global histogram stretching technique, local histogram stretching was implemented to further refine image contrast enhancement. This approach divides the Region of Interest (ROI) into four equal quadrants and applies histogram stretching independently to each quadrant using the same intensity range parameters (A, B). This method allows for localized contrast adjustments, accommodating variations in lighting or intensity within different parts of the image.

For the demonstration, the baboon.png image's selected ROI was subjected to local histogram stretching, with each quadrant being processed separately. The parameters A=50 and B=235 were consistently applied to all quadrants. This localized approach to histogram stretching ensures that each section of the ROI receives tailored contrast enhancement, leading to a more balanced and detailed overall image.

Figure 3 illustrates the result of local histogram stretching applied to the ROI of the baboon.png image. The image is divided into four quadrants, each enhanced individually, resulting in a uniformly improved contrast across the entire ROI.

**Figure 3**

**Close-up of a baboon's face

Description automatically generated**

Local histogram stretching proves advantageous in scenarios where different regions of an image exhibit diverse characteristics in terms of lighting and detail. By applying histogram stretching to smaller, localized areas, this method ensures that each part of the image is optimally enhanced, leading to a more detailed and visually appealing result.

**3.3 Augmentation of Grayscale Images Through Rotation**

In addition to histogram modifications, image augmentation was further explored through the rotation of images. This process involves generating new images by rotating the original or modified images at specific angles, providing different perspectives and variations of the same scene.

For this part of the assignment, the following operations were performed:

* Rotation of Original ROI: The original ROI extracted from the baboon.png image was rotated at angles of 90, 180, and 270 degrees.
* Rotation After Global Histogram Stretching: The ROI, after undergoing global histogram stretching with parameters A=50 and B=235, was then rotated at the same set of angles.
* Rotation After Local Histogram Stretching: Following the application of local histogram stretching to the ROI, the image was again rotated at 90, 180, and 270 degrees.

Figure 4 presents the series of images generated from the local histogram-stretched ROI (baboon\_local\_stretch.pgm) after rotations of 90, 180, and 270 degrees. These images illustrate the diverse perspectives obtained through rotation, enriching the dataset with varied orientations.

**Figure 4**

**Close up of a monkey

Description automatically generated** **Close-up of a baboon's face

Description automatically generated**

**Close-up of a bat's face

Description automatically generated**

**3.4 Sliding-Window Histogram Processing**

For extra credit, a sliding-window approach to local histogram processing was implemented, offering a more nuanced method of image contrast enhancement. This technique involves adjusting the histogram of each pixel based on the intensity values within a specified window surrounding it, thus providing localized contrast adjustments.

Sliding-Window Parameters: The sliding window size was set to 5, with the stretching parameters A and B being 120 and 180, respectively. This configuration ensures that each pixel's intensity is adjusted according to the local histogram within its immediate 5x5 neighborhood, leading to a more detailed and locally adapted contrast enhancement.

Figure 5 showcases the result of applying sliding-window histogram processing to the original image with the specified parameters. This image illustrates the effect of localized histogram stretching, where contrast enhancements are tailored to specific regions, enhancing details and textures within the image.

**Figure 5**

**A close-up of a baboon

Description automatically generated**

The sliding-window histogram processing technique provides a refined approach to image enhancement, allowing for localized adjustments that cater to the varying contrast requirements across different parts of an image. This method is particularly beneficial for images with uneven lighting or those requiring detailed enhancement in specific areas.

**3.4 Augmentation of Color Images**

In the color processing segment, the focus was on applying local histogram modifications to color images. This involved selectively enhancing the R, G, and B components of an image, either individually or collectively, to adjust the color balance and contrast.

The toolbox was expanded to include functions capable of modifying the histogram of individual color channels within an image. This allowed for nuanced adjustments in color balance and intensity, providing a means to enhance specific aspects of an image's color composition.

Figure 6 presents the original color ROI from the baboon image, serving as the baseline for subsequent color processing operations.

**Figure 6**

**Close up of a bird's face

Description automatically generated**

Figure 7 showcases the outcomes of applying local histogram modifications to different color channels:

* The first image illustrates the effect of enhancing the red (R) component, resulting in a pronounced emphasis on red hues within the image.
* The second image demonstrates the modification of the green (G) component, highlighting green areas and enhancing vegetation and other green features.
* The third image shows the adjustment of the blue (B) component, which may enhance skies, water bodies, and other blue elements.
* The fourth image displays the combined adjustment of all R, G, B components, offering a balanced enhancement across the color spectrum.

**Figure 7**

**A close up of a bird

Description automatically generated** **A close up of a bird's face

Description automatically generated**

**A close up of a bird's face

Description automatically generated** **A close-up of a screen

Description automatically generated**

Following the color adjustments, the images were further processed through a series of rotations to generate additional augmented versions, enriching the dataset with varied orientations and perspectives.

Figure 8 includes four representative images from the augmented set:

* The first image shows the R component-enhanced image rotated by 90 degrees, offering a new perspective with emphasized red tones.
* The second image depicts the G component-enhanced image after a 180-degree rotation, presenting an inverted view with pronounced green hues.
* The third image illustrates the B component-enhanced image rotated by 270 degrees, providing a counter-clockwise twist with enhanced blue elements.
* The fourth image combines the full RGB enhancement followed by a 90-degree rotation, blending the color enhancements with a fresh orientation.

**Figure 8**

**A close up of a bug

Description automatically generated** **A close-up of a bird

Description automatically generated**

**A close up of a butterfly

Description automatically generated** ****

**4. Discussion of Results**

The application of histogram modification and color processing significantly enhanced image details and contrast. Global histogram stretching effectively improved overall contrast, while local stretching and sliding-window techniques offered fine-grained improvements by addressing local variations. Color processing allowed for targeted adjustments in specific channels, providing a versatile tool for image augmentation. The consistent quality of results across various rotations confirmed the robustness of these methods. These techniques prove valuable in diverse areas like photography, medical imaging, and computer vision.

**5. Conclusion**

The exploration of histogram modification and color processing techniques in this assignment has underscored their potential in enhancing and transforming images. These methods not only improve image quality but also offer creative tools for image manipulation. The sliding window approach highlights the importance of considering local image characteristics for more sophisticated enhancements. As we continue to delve deeper into image processing, the ability to selectively adjust image attributes will undoubtedly play a crucial role in both analytical and artistic applications.