**Assignment 1: Enhanced Image Processing Toolkit**

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**1. Introduction**

This report elaborates on the HW-0 assignment, emphasizing foundational image processing techniques facilitated by the OpenCV library. This project extends an existing image manipulation program by introducing advanced features for processing both grey-level and color images. Through a carefully designed interface and algorithmic enhancements, users can select regions of interest (ROI), apply a range of transformations, and generate augmented images.

**2. Implementation and Algorithm Concepts**

The project's framework is constructed around fundamental image manipulation algorithms, optimized for both simplicity and efficacy. This section discusses the key implementations.

**ROI Processing:**

* **ROI Selection**: Targets specific image areas for focused manipulation, enhancing computational efficiency and preserving the quality of non-selected regions.
* **Independent Processing**: Facilitates distinct transformations within each ROI, offering versatility in localized image enhancements.

**Grey-Level Augmentation:**

* **Pixel Manipulations**: Directly alters pixel values within ROIs for brightness adjustments and binarization, employing functions like **add\_Grey\_ROI** and **binarize\_Grey\_ROI**.
* **Spatial Transformations**: Implements basic image flipping and rotation, generating diverse orientations from original ROIs to enrich the dataset.

**Color Image Augmentation:**

* **Color Adjustments**: Introduces multiplicative (**multiplyC**) and additive (**addC**) methods for color brightness modification, catering to nuanced color intensity and overall brightness alterations.
* **Flipping and Rotating**: Extends flipping and rotating capabilities to color images, ensuring precise spatial manipulation of three-channel color data.

**3. Results with Parameters**

**3.1 Processing of Grey-Level Images**

The enhancement of our image processing toolkit now includes advanced functionality for handling Regions of Interest (ROI) within grayscale images, a significant step forward from the basic operations provided in HW0. This section delves into the specifics of ROI selection and the adaptation of existing functions to operate within these specified regions.

The toolkit now supports the precise definition of up to three ROIs within a single image, specified by the coordinates (X, Y) of the top-left pixel and the size (S) of the square region. This feature allows for targeted image processing, enabling users to apply modifications to specific image areas without affecting the entire image. The flexibility of overlapping ROIs further enhances this capability, allowing for intricate and layered image manipulations.

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**Figure 1: Original baboon.png image alongside a processed version with up to three ROIs, each undergoing a combination of binarize, add, and decrease brightness operations.**

All pre-existing functions, except for scaling, have been adapted to operate exclusively within the defined ROIs. This adaptation includes operations such as pixel addition, binarization based on a threshold, and brightness reduction below a specified threshold. Each ROI can be processed with different parameters, providing a high degree of customization and control over the image manipulation process.

To illustrate these enhancements, we applied a combination of binarize, add, and decrease brightness functions to up to three different ROIs within the original baboon.png image. Figure 1 showcases the original image alongside the processed image, highlighting the precise and localized effects of the applied operations within the specified ROIs. This example demonstrates the toolkit's ability to perform complex image manipulations, offering users a powerful tool for image analysis and artistic creation.

**3.2 Augmentation of Grey-Level Images**

In this section, we explore the augmentation capabilities of our image processing toolkit, specifically focusing on the transformation of Regions of Interest (ROI) within grayscale images. The toolkit now supports generating multiple variations of a selected ROI through operations such as flipping, rotating, scaling, and brightness adjustment.

The toolkit allows for the extraction of an ROI from the original image, followed by the generation of three new images through flipping and rotating operations. These operations include horizontal flipping, rotating 90 degrees clockwise, and rotating 90 degrees counterclockwise. This set of transformations provides a simple yet effective means of augmenting image data, useful in various applications such as data augmentation in machine learning models.

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**Figure 2: The original ROI extracted from baboon.png alongside the flipped version of the ROI, demonstrating the toolkit's capability to manipulate image orientation.**

Further augmenting the toolkit's capabilities, we introduced a scaling function that enlarges the selected ROI by a specified scale factor (SC) while maintaining the original image size. This operation is particularly useful for focusing on specific image details. The scaled ROIs can then undergo additional transformations, such as flipping and rotating, to generate varied perspectives of the same region.

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**Figure 3: A sequence showcasing the original ROI scaled by a factor and subsequently rotated 90 degrees clockwise, illustrating the combined effects of scaling and rotation.**

Another augmentation feature involves modifying the brightness of the selected ROI before applying additional transformations. By increasing or decreasing the brightness (BR) within the specified range, users can generate variations of the ROI that differ in luminance. These brightness-adjusted ROIs can then be flipped and rotated, further expanding the set of generated image variations.

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**Figure 4: Illustration of brightness adjustment applied to the original ROI, followed by a 90-degree counterclockwise rotation, showcasing the toolkit's ability to alter and reorient image luminance.**

These augmentation functions enhance the toolkit's versatility, enabling users to generate a diverse set of images from a single ROI. This capability is invaluable for tasks that require varied image data from a limited set of original images, such as training robust machine learning models or conducting detailed image analyses.

**3.3 Augmentation of Color Images**

This section delves into the augmentation of color images, focusing on transformations applied to Regions of Interest (ROI) extracted from the original color images. The enhancement involves generating new images through flipping, rotating, and modifying color brightness, both multiplicatively and additively.

Starting with the basic transformations, the original color ROI can be manipulated to produce three distinct images by applying flipping, 90-degree clockwise rotation, and 90-degree counterclockwise rotation. These transformations allow for the exploration of different orientations and perspectives of the same color ROI, enriching the dataset with varied visual representations.

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**Figure 5: Displays the original color ROI extracted from baboon\_color.png, setting the stage for subsequent color transformations.**

The toolkit introduces a novel feature for color images: multiplicative color brightness modification. By adjusting the brightness of each color channel (R, G, B) using a specified factor (More-C), users can enhance or diminish the vibrancy of the color ROI. This modified ROI can then undergo flipping and rotation, yielding three new images that combine altered color intensity with spatial transformations.

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**Figure 6: Illustrates the process of applying a multiplicative color brightness modification (factor 1.9) to the color ROI, followed by flipping and rotating the modified ROI to generate additional image variations.**

Expanding the color augmentation capabilities, the toolkit also offers additive color brightness modification. This function adjusts the brightness of each color channel (R, G, B) by adding a specified value (AC), ensuring the resultant color values remain within acceptable bounds. The brightness-adjusted ROI can then be flipped and rotated, like the previous steps, creating a set of images that showcase both color and orientation diversity.

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**Figure 7: Depicts the initial additive color brightness modification (value +100) applied to the color ROI, followed by the creation of three derivative images through flipping and rotation, demonstrating the impact of additive color adjustments on image aesthetics.**

Through these color augmentation techniques, the toolkit empowers users to generate a rich assortment of images from a single-color ROI. This functionality is particularly beneficial for tasks that demand a diverse visual dataset, such as training data for machine learning algorithms or comprehensive image analysis projects, providing a broader perspective on the original color content.

**4. Discussion of Results**

The results showcase the effectiveness of implementing region-specific manipulations and augmentations in both grey-level and color images. Key observations include the enhanced flexibility in processing localized regions, the ability to generate varied datasets through simple transformations, and the nuanced control over image coloration. These capabilities are crucial for applications requiring detailed image analysis and dataset diversification, such as in machine learning and computer vision.

**5. Conclusion**

This assignment demonstrates a comprehensive approach to basic image processing, emphasizing ROI-based manipulations and color augmentations. The techniques explored provide a solid foundation for more advanced image processing tasks, highlighting their potential for creating varied and enhanced datasets. The successful application of these methods illustrates their importance in the broader context of image analysis and machine learning.