Homework: 11
Image Enhancement and Reconstruction using Linear and Non-linear Operations

Name: Md. Al-Amin Babu
ID: 2110676134

Objective

The main objective of this assignment is to apply different **image enhancement techniques** using both linear and non-linear transformations, along with histogram equalization methods, to improve the visibility and contrast of a grayscale image.

Furthermore, the image is divided into smaller sections, individually enhanced using different transformations, and later reconstructed to analyze the combined effects.

Short Discussion on Implemented Operations

1. Input Image and Preprocessing

The grayscale image is first loaded using OpenCV. It is then divided into a 3×3 grid using a custom function so that each part can be processed with different transformations.

2. Linear Operations

Two types of linear intensity transformations are implemented:

- **Linear Operation 1:**
$$I' = \alpha I + \beta$$
Increases both contrast and brightness — this operation brightens the image and emphasizes mid-tones.

- **Linear Operation 2:**
$$I' = \alpha I - \beta$$
Enhances contrast while slightly darkening the image, useful for reducing overexposure.

3. Gamma (Non-linear) Operations

Gamma correction is applied to adjust brightness non-linearly.

- **Gamma Operation 1:** $\gamma = 0.6$ — darkens shadow areas, compressing tone.
- **Gamma Operation 2:** $\gamma = 0.2$ — brightens dark regions and reveals hidden details.

Each of these operations is applied on different divided tiles cyclically.

4. Divide and Combine Functions

Two key helper functions manage the segmentation and reconstruction:

- `divide_image(img, s)` — Divides the image into $s \times s$ blocks.
- `combine_image(parts, s, ph, pw)` — Combines all processed tiles into a complete reconstructed image.

5. Histogram-based Enhancement

After reconstruction, the following histogram equalization techniques are applied for comparison:

1. **Histogram Equalization (HE):** Improves global contrast.
2. **Adaptive Histogram Equalization (AHE):** Enhances local contrast but may increase noise.
3. **Contrast Limited AHE (CLAHE):** Adds clipping limit to control noise and over-brightness.
4. **AHE + Bilinear Interpolation:** Combines AHE with interpolation to smooth pixel transitions.

6. Visualization and Outputs

The processed images are displayed using `matplotlib`. The following output files are generated:

- **main_img.png** — Original grayscale image.
- **divided_img.png** — Divided 3×3 tiles after applying different operations.
- **reconstructed_img.png** — Combined image after processing all tiles.
- **different_operation.png** — Comparison of HE, AHE, CLAHE, and AHE+Bilinear.

Results and Discussion

(a) Original Image

Figure 1: Original grayscale image used for enhancement.

(b) Divided Image with Various Operations

Figure 2: Image divided into 3×3 tiles; each processed using a unique operation (Linear or Gamma).

(c) Reconstructed Image

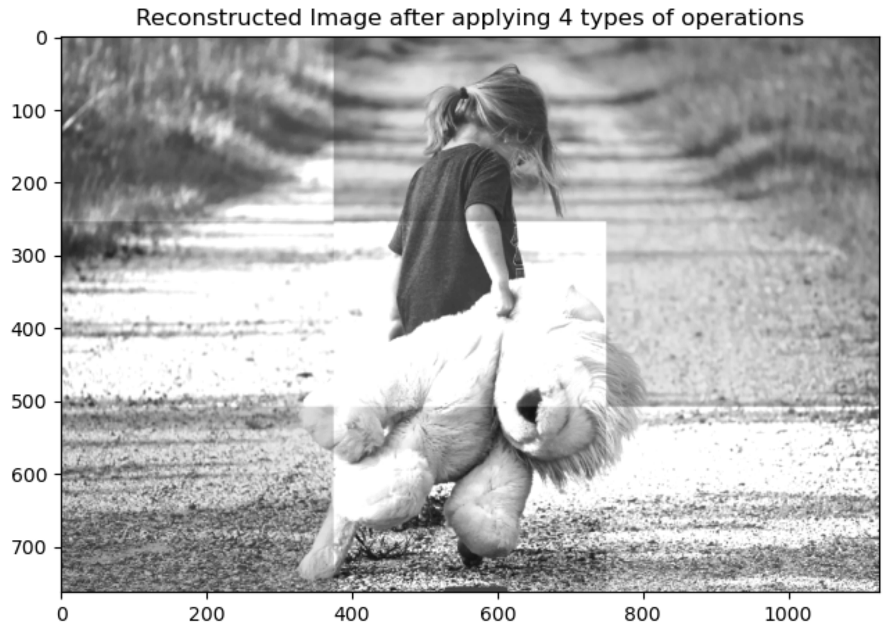

Figure 3: Reconstructed image after applying four different intensity operations.

(d) Comparison of Enhancement Techniques

Figure 4: Comparison of different enhancement methods (HE, AHE, CLAHE, and AHE+Bilinear).

Code Link

The complete source code for this assignment is available at the following link:
Click here to view the code into github.

Conclusion

This experiment demonstrates the significance of both global and local enhancement techniques.

- **HE** provides uniform contrast enhancement but can cause loss of detail.
- **AHE** boosts local contrast, suitable for uneven lighting.
- **CLAHE** limits over-enhancement and maintains natural tone balance.
- **Linear and Gamma corrections** offer flexible manual tone adjustment.

By combining these methods, we can achieve visually improved and more informative images — beneficial for medical, remote sensing, and photography applications.