3 Contrast Enhancement

3.1 Linear Contrast Stretching

Function: `myLinearContrastStretch()`
Summary: Simply applying linear contrast by linear scaling the luminance channel of the original image does not render the optimal result. Since out of the 1.4M pixels in the image, around 9000+ pixels lie in the 0.5 to 1.0 pixel range.

Hence, we must mask and ignore these pixels with luminance > 0.5 to get our final contrasted image!

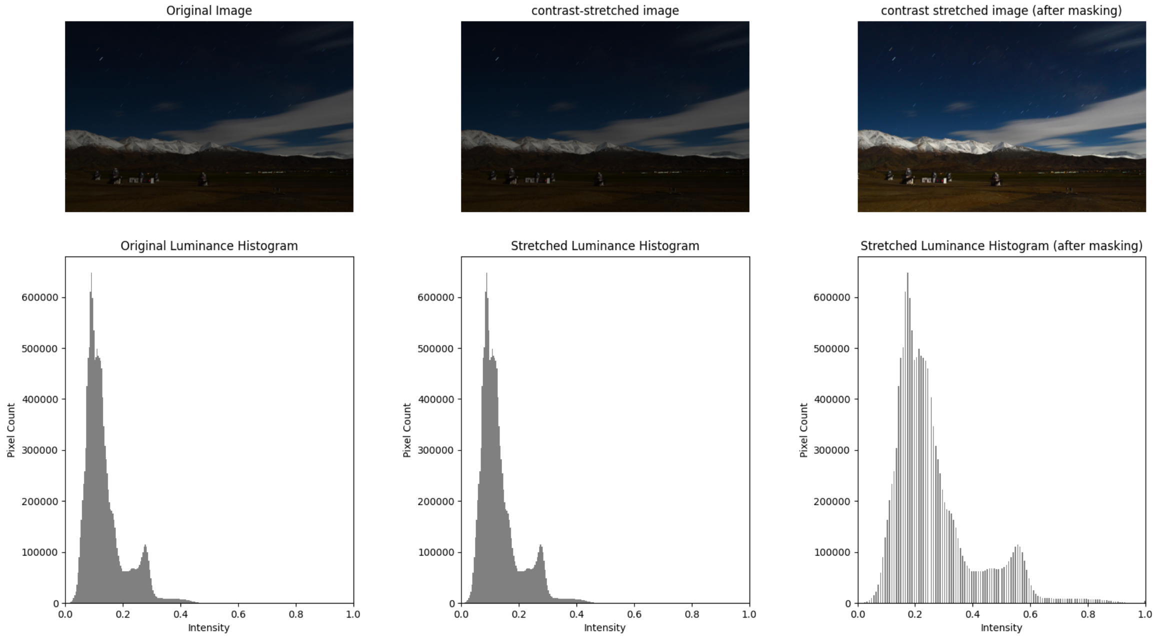

Figure 1: Linear contrast stretching results.

3.2 Histogram Equalization

Function: `myHistEqualize()`
Summary:

Given an image in RGB space, we first convert it to HSV and operate on the luminance component $V(x, y) \in [0, 1]$. A binary mask is defined as

$$M(x,y) = \begin{cases} 1, & V(x,y) \leq T, \\ 0, & V(x,y) > T, \end{cases}$$

where T is the luminance threshold (e.g., $T = 0.5$). Only pixels with $M(x, y) = 1$ are equalized.

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Step 1: Discretization. The masked pixel intensities are quantized into L discrete levels ($L = \text{num\_bins}$):

$$v_q = \text{round}\big(V(x,y) \cdot (L-1)\big), \quad v_q \in \{0, 1, \ldots, L-1\}.$$

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Step 2: Histogram and CDF. The histogram of quantized values is

$$h(k) = \#\{(x,y) \mid v_q(x,y) = k,\ M(x,y) = 1\}, \quad k = 0, 1, \dots, L-1.$$

The cumulative distribution function (CDF) is

$$\mathrm{CDF}(k) = \sum_{i=0}^{k} h(i).$$

We normalize it as

$$\hat{F}(k) = \frac{\mathrm{CDF}(k)}{\max_j \mathrm{CDF}(j)}.$$

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Step 3: Equalization mapping. Each masked intensity v_q is mapped using

$$v_q' = \hat{F}(v_q)\,(L-1).$$

The equalized luminance is then

$$V'(x,y) = \begin{cases} \dfrac{v_q'}{L-1}, & M(x,y) = 1, \\ V(x,y), & M(x,y) = 0. \end{cases}$$

Thus, histogram equalization redistributes the intensity values of masked pixels so that their histogram becomes approximately uniform, enhancing contrast in dark regions while preserving unmasked regions.

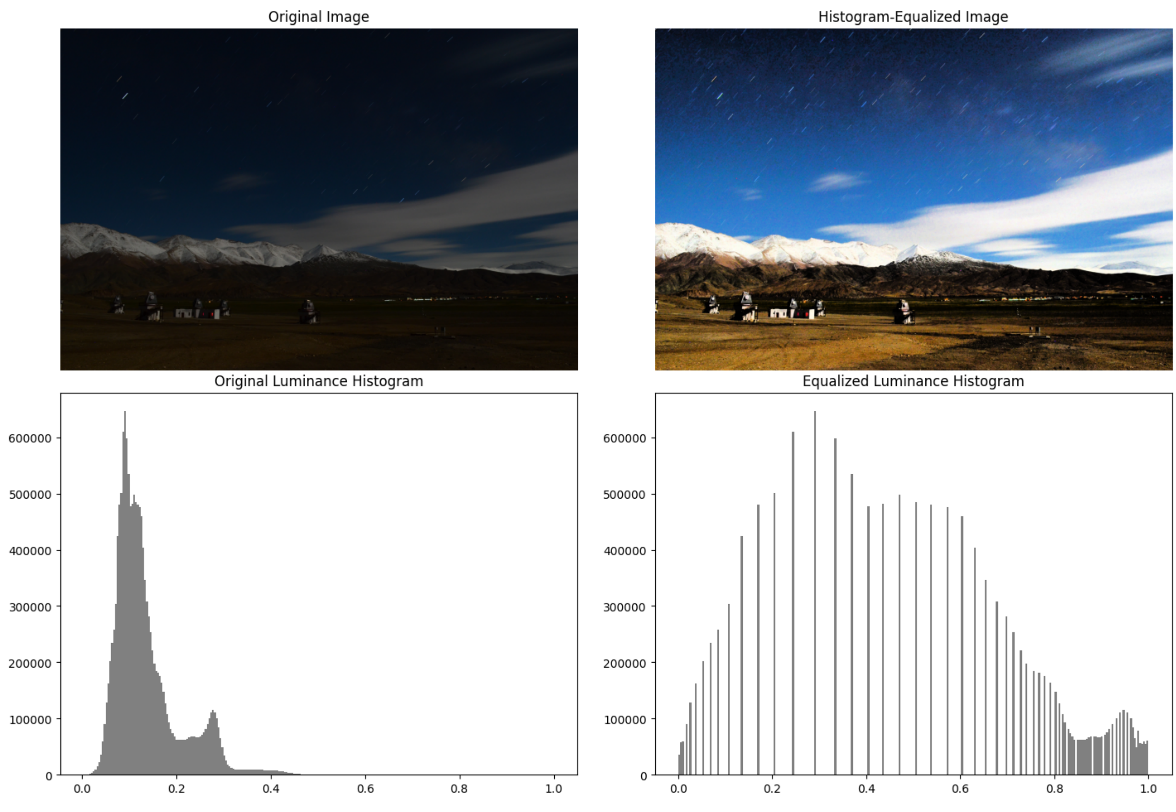

Figure 2: Linear contrast stretching results.

3.3 CLAHE

Function: `myCLAHE()`
Summary:

Given an image in CIELab color space, with luminance $L(x, y) \in [0, 100]$ and chroma channels $a(x, y), b(x, y)$, we apply CLAHE on the luminance channel while preserving chroma.

CLAHE adaptively enhances local contrast by equalizing histograms within small tiles, while limiting contrast amplification using the clip limit parameter γ.

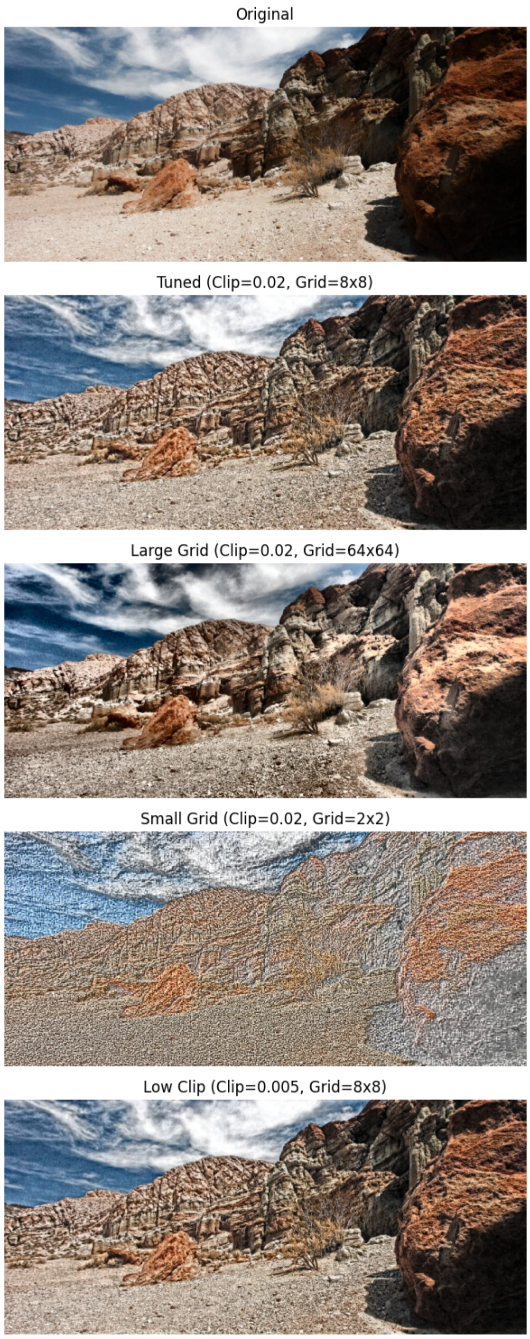

Figure 3: CLAHE results for different grid size and clip

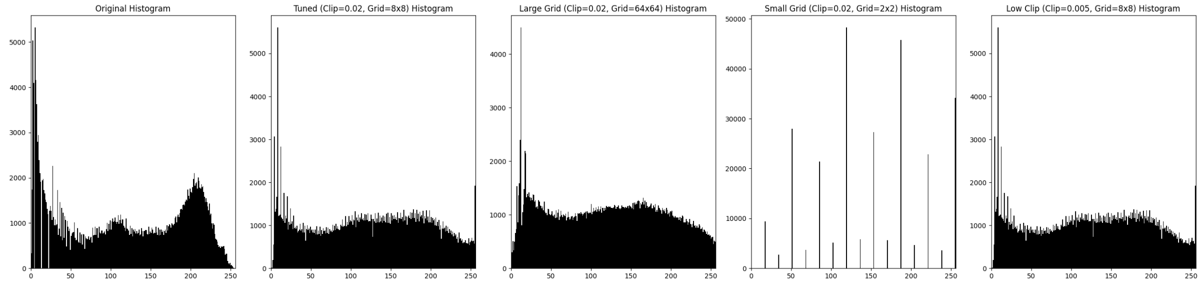

Figure 4: Linear contrast stretching results.

3.4 Histogram Matching

Function: `myHistMatch()`
Histogram Matching:

Given a source image I_s and a reference image I_r, the goal of histogram matching is to transform the intensity distribution of I_s so that it resembles that of I_r. The process is carried out independently on the L, a, and b channels of the Lab color space, while ignoring black background pixels.

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Step 1: Conversion to Lab color space. The input images are transformed:

$$I_s^{Lab} = \mathrm{RGB2Lab}(I_s), \quad I_r^{Lab} = \mathrm{RGB2Lab}(I_r).$$

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Step 2: Foreground masking. Background pixels are removed by thresholding the luminance channel:

$$M_s(x,y) = \begin{cases} 1, & L_s(x,y) > 5, \\ 0, & \text{otherwise}, \end{cases} \qquad M_r(x,y) = \begin{cases} 1, & L_r(x,y) > 5, \\ 0, & \text{otherwise}. \end{cases}$$

Only pixels with mask value 1 are considered in subsequent steps.

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Step 3: Histogram and CDF computation. For each channel $c \in \{L, a, b\}$, compute the histograms:

$$h_s^c(k) = \#\{(x,y) \mid I_s^c(x,y) = k,\ M_s(x,y) = 1\},$$

$$h_r^c(k) = \#\{(x,y) \mid I_r^c(x,y) = k,\ M_r(x,y) = 1\}.$$

The cumulative distribution functions (CDFs) are

$$\mathrm{CDF}_s^c(k) = \sum_{i=0}^{k} h_s^c(i), \quad \mathrm{CDF}_r^c(k) = \sum_{i=0}^{k} h_r^c(i).$$

Both are normalized to $[0, 1]$.

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Step 4: Mapping function. A mapping is constructed by matching equalized source intensities to the closest reference intensities:

$$T^c(v) = \arg\min_j \left|\mathrm{CDF}_s^c(v) - \mathrm{CDF}_r^c(j)\right|.$$

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Step 5: Transformation of source image. Each foreground pixel in the source channel is remapped:

$$I_s^{c'}(x, y) = T^c\big(I_s^c(x, y)\big), \quad \text{if } M_s(x, y) = 1.$$

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Step 6: Reconstruction. The modified Lab image is

$$I_s^{Lab'} = \big(I_s^{L'}, I_s^{a'}, I_s^{b'}\big),$$

and the final RGB image is obtained by

$$I_s^{RGB'} = \mathrm{Lab2RGB}(I_s^{Lab'}).$$

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Thus, histogram matching aligns the intensity distributions of the source image to the reference image, producing a perceptually closer appearance while ignoring background pixels.

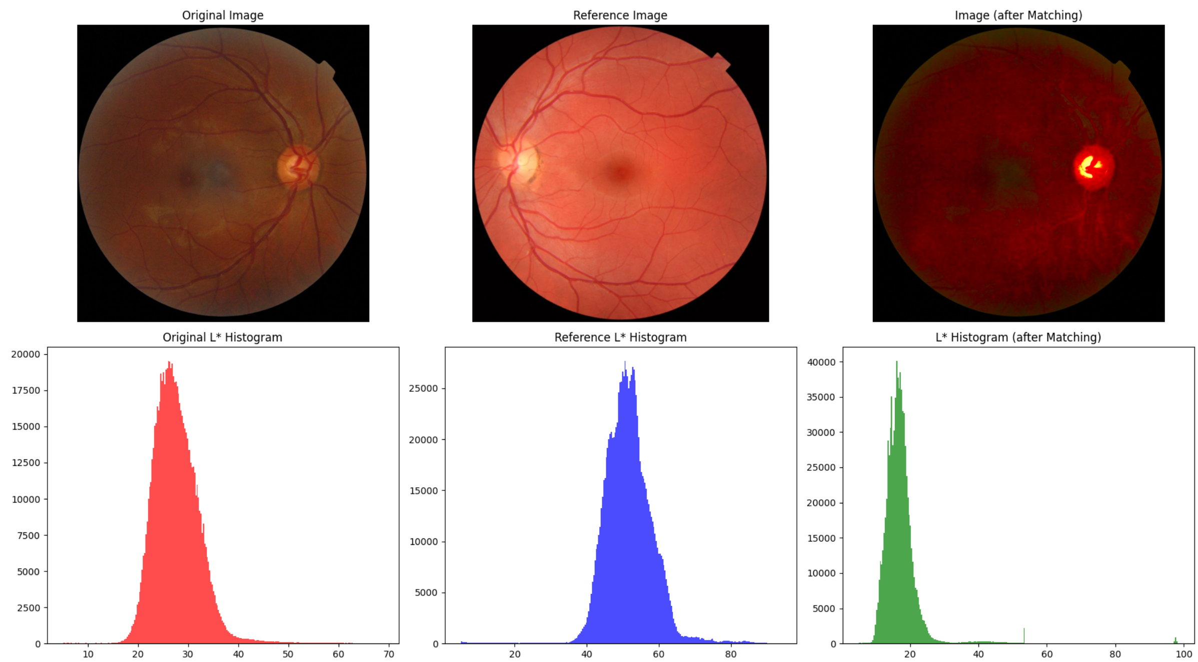

Figure 5: CLAHE results for different grid size and clip