Contrast Enhancement through Normalization

Assume the input image is I, and its dynamic range is low.

We can increase the dynamic range [0 255] using the below equation

$$I_n = \frac{I - I_{mn}}{I_{mx} - I_{mn}} \times 255$$

I Input Image (low dynamic range)

I_n Output Image (Contrast enhanced image)

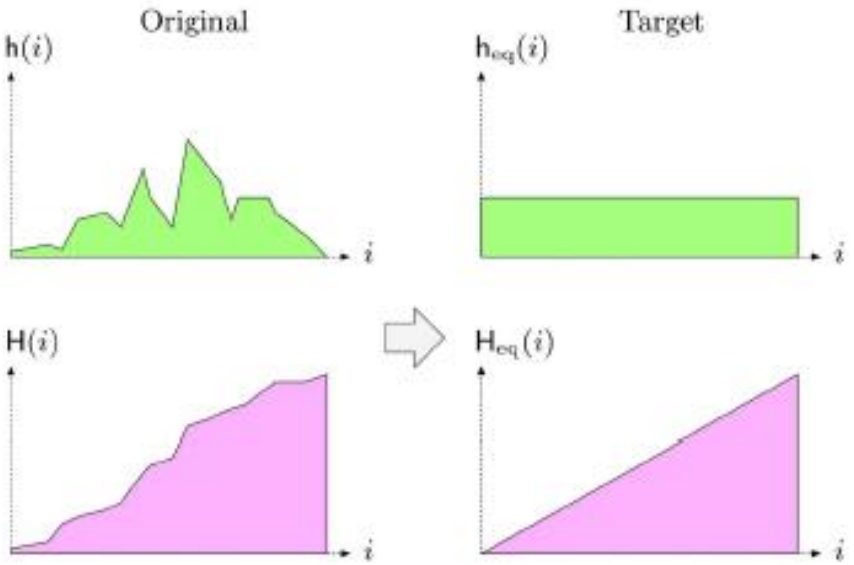
I_{mx} Maximum value in the input image

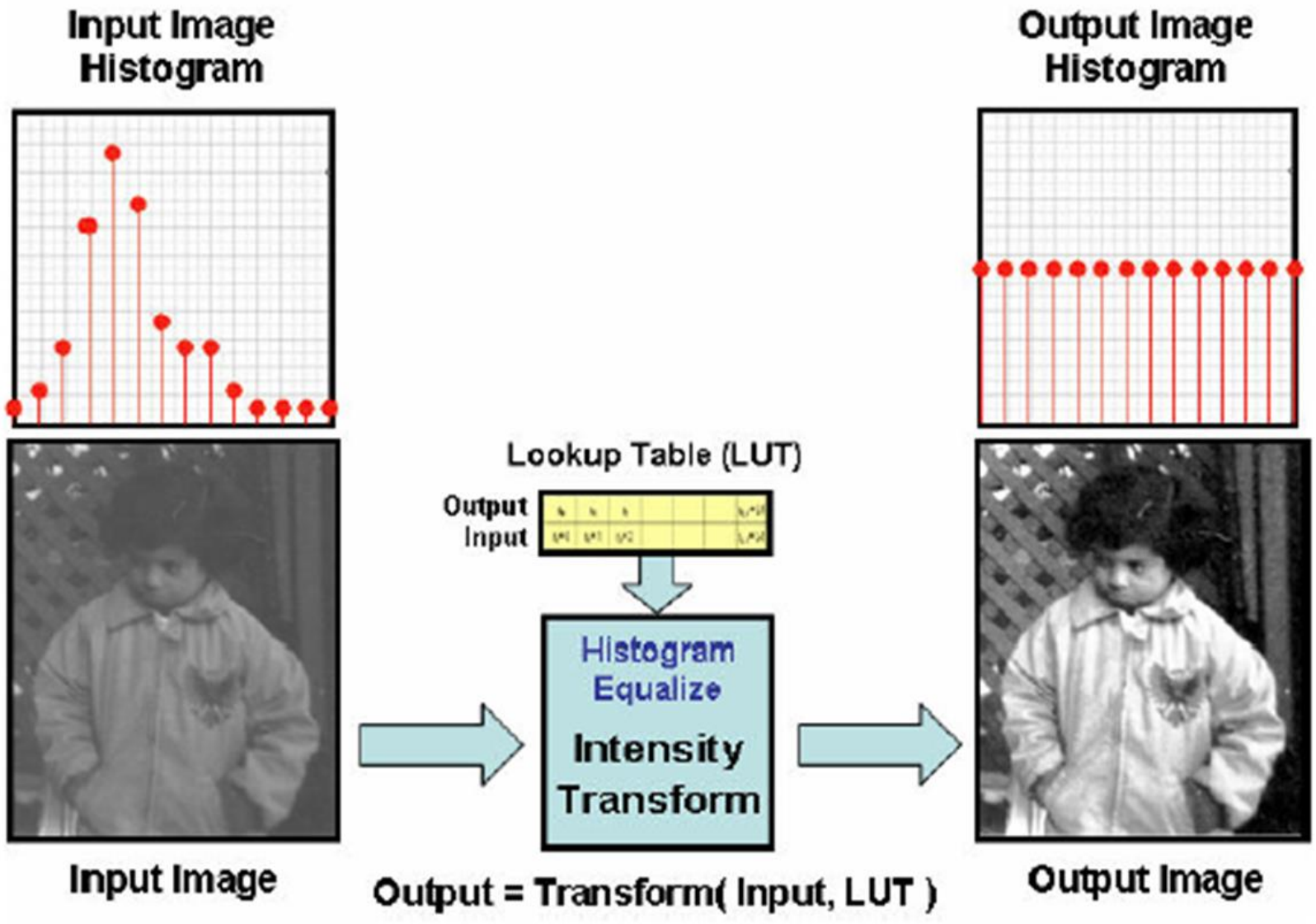
I_{mn} Minimum value in the input image

Histogram Equalization

Apply a point operation that changes histogram of modified image into uniform distribution.

This process improves the contrast of the image.




Input Image Histogram
Output Image Histogram
Lookup Table (LUT)
Output
Input
Histogram Equalize
Intensity Transform
Input Image
Output = Transform(Input, LUT)
Output Image

Histogram Equalization

Spreading out the frequencies in an image (or equalizing the image) is a simple way to improve dark or washed out images

Can be expressed as a transformation of histogram

- r_k: input intensity
- s_k: processed intensity
- k: the intensity range (e.g 0.0 – 1.0)

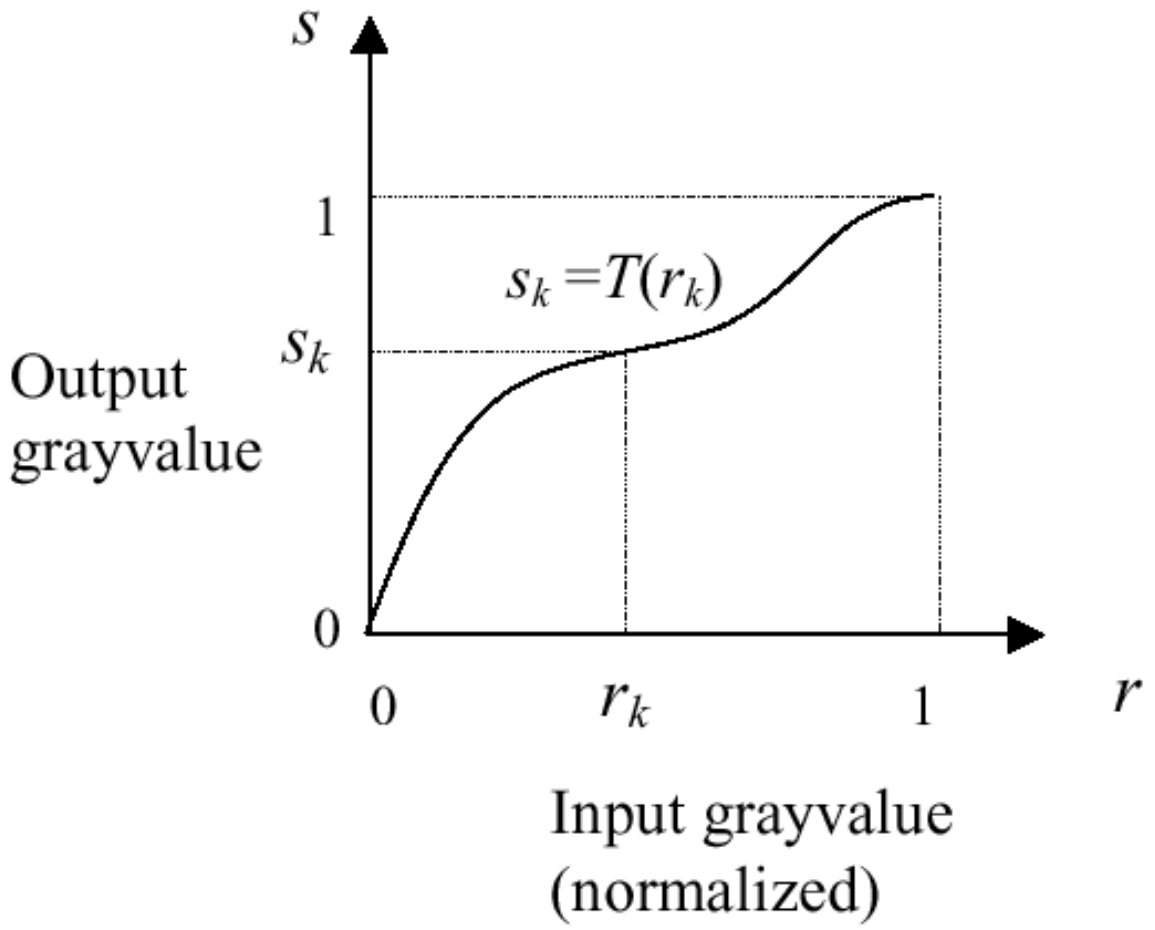
processed intensity → $s_k = T(r_k)$ ← input intensity

Intensity range (e.g 0 – 255)

We assume that:

(1) *T(r)* is a monotonically increasing function for $0 \leq r \leq 1$ (preserves order from black to white).

(2) *T(r)* maps [0,1] into [0,1] (preserves the range of allowed Gray values).



Cumulative Histogram

- Useful for certain operations (e.g. histogram equalization) later
- Analogous to the Cumulative Density Function (CDF)
- Definition:

$$\mathsf{H}(i) = \sum_{j=0}^{i} \mathsf{h}(j) \quad \text{for} \;\; 0 \le i < K$$

- Recursive definition

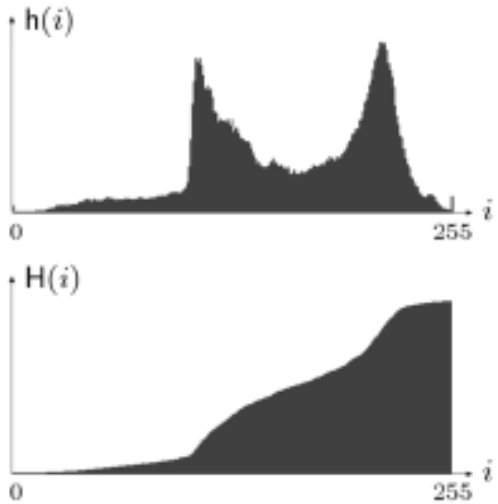
$$\mathsf{H}(i) = \begin{cases} \mathsf{h}(0) & \text{for} \;\; i = 0 \\ \mathsf{H}(i-1) + \mathsf{h}(i) & \text{for} \;\; 0 < i < K \end{cases}$$

- Monotonically increasing

$$\mathsf{H}(K-1) = \sum_{j=0}^{K-1} \mathsf{h}(j) = M \cdot N$$

Last entry of Cum. histogram

Total number of pixels in image



Histogram Equalization

1. Compute the histogram of the image. Let the histogram, of the image I be H_I

2. Compute the probability density function of the Image

$$P_i = \frac{H_i}{\sum_{j=1}^{n} H_j}$$

3. Compute the cumulative density function C

4. Apply the transformation as follows

$$g\ (i,j) = \text{floor}\ [(L-1) \times C\big(I(i,j)\big)]$$

where g is the contrast enhanced image and I is the input image.