

# HISTOGRAM EQUALIZATION

Histogram equalization is an **image processing technique** meant to **enhance the contrast** of an image by **redistributing its intensity values**. The pixel values are adjusted according to the **histogram** of the image in this process with the intention of **uniform distribution of intensity**, and therefore, enhancement of image details. By using the full dynamic range, histogram equalization allows for a better **use of intensity levels**, which is most advantageous for low-light or highly contrasted images.

## HOW HISTOGRAM EQUALIZATION WORKS?

Histogram equalization works through a **nonlinear mapping of the pixel intensity**. It computes the histogram, which gives the **occurrence of each level of intensity**. The histogram is **normalized** and **then transformed** into the **cumulative distribution function**, or CDF. If original pixel values are mapped through that CDF, the contrast of the resulting image will usually be increased and the **distribution of intensities will tend to become uniform**, which produces a **flat histogram**. Particularly useful for images in **grayscale and low-light**, although it can also be applied to each of the **color channels separately for RGB images**.

## STEPS OF HISTOGRAM EQUALIZATION

1. **Compute the Histogram:** This histogram is the frequency of all intensity levels in the given image.
2. **Normalize the Histogram:** Scale the histogram to a range of  $[0, 1]$  in order to form a cumulative probability function.
3. **Construct a Lookup Table:** Using the cumulative histogram, create a lookup table that will convert input intensities to equalized values.
4. **Adjust the Image:** Apply the lookup table to transform pixel values in the input image to their new, equalized intensities.

## APPLICATIONS IN IMAGE PROCESSING

Histogram equalization is widely used in all fields of **image processing** and **computer vision**. It can be used to **enhance contrast in X-rays or MRI scans** for medical imaging purposes. For the skin lesion analysis, histogram equalization can be applied on the **luminosity channel of an image**, which may further improve the **segmentation and feature extraction** of skin abnormalities.

## TYPES OF HISTOGRAM EQUALIZATION

There are two main techniques of histogram equalization.

- **Global Histogram Equalization (GHE):** It uniformly adjusts the histogram of whole images. It is efficient but creates over-enhancement in regions having homogeneous intensity levels.
- **Adaptive Histogram Equalization (AHE):** Divides the image into small regions and applies histogram equalization locally, thereby allowing better contrast in specific regions and over-enhancement risk is minimized. It is useful for images containing different intensities, such as hazy or medical images.

## BENEFITS AND LIMITATIONS

Although histogram equalization is computationally efficient and is applied in wide intervals of applications, there are some limitations in it. **Over-enhancement** may create unwanted artifacts or loss of detail, especially in uniformly intense regions. It often uses the contrast-limited adaptive histogram equalization (**CLAHE**), limiting amplification of the intensity to avoid over-enhancement and loss of details to save the image quality and reduce the noise itself.

Simply stated, histogram equalization remains the most fundamental image-processing technique that offers redistribution of the intensity values of the pixels such as to enhance the contrast among images and for visual clearness. Despite the shortcomings thereof, it remained the general choice for applications that should require higher visibility and larger details in digital images.