# Image Analysis

## 2. Image Restoration / a. Contrast Enhancement

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## 1. Histogram Equalization

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# Brightness Histogram

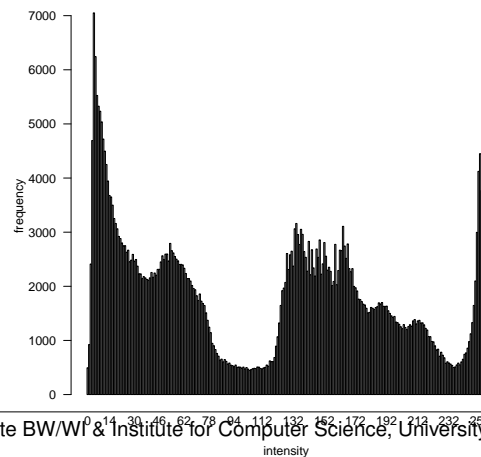Let
$$f : X \times Y \to I := \{0, 1, \ldots, I_{\max}\}$$
be a discrete image.

Its **brightness histogram** $h : I \to \mathbb{N}$ describes how often a specific brightness value $i \in I$ occurs in the image $f$:

$$h(i) := |f^{-1}(i)| := |\{(x, y) \in X \times Y \mid f(x, y) = i\}|$$



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# Low Contrast

Low contrast often means that the available brightness range is not optimally used.
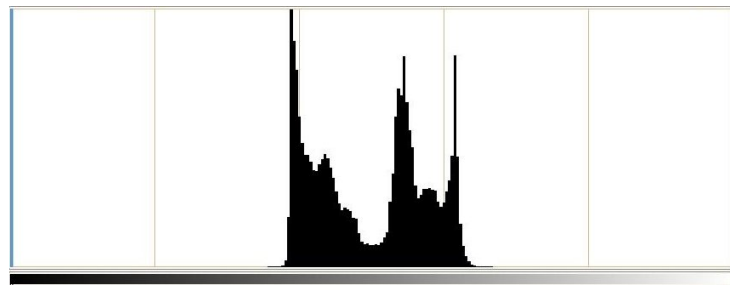
Example:



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# Histogram Equalization

To make better use of the available brightness range,
one can spread the brightness values equally over the full range.

For a brightness histogram $h : I \to \mathbb{N}$, define its **cumulative brightness frequency** as

$$
\begin{aligned}
H : I &\to \mathbb{N} \\
i &\mapsto \sum_{j \leq i} h(j)
\end{aligned}
$$
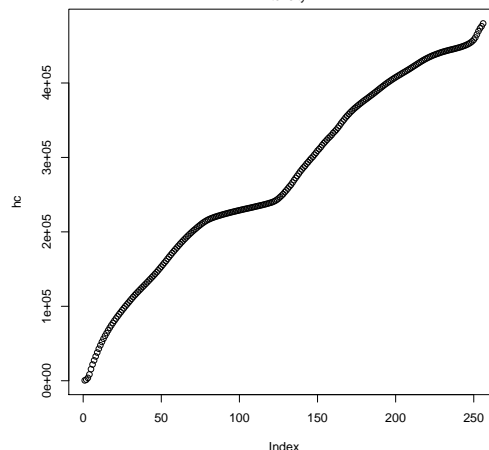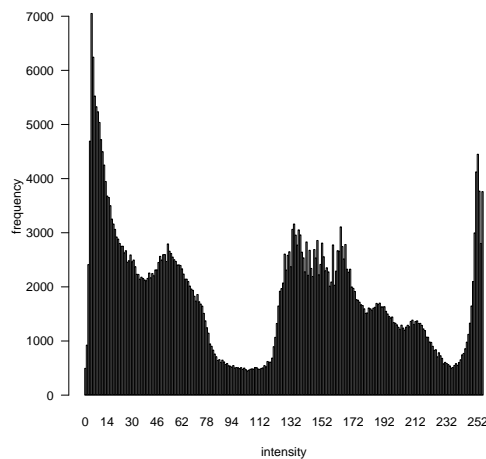
Transform the brightness $i$ to

$$
\text{equalize}(i) := \text{round}(H(i) \frac{I_{\max}}{|X| \cdot |Y|})
$$

Apply this transform to all pixels:

$$
f'(x, y) := \text{equalize}(f(x, y))
$$

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## After Histogram Equalization

Example:
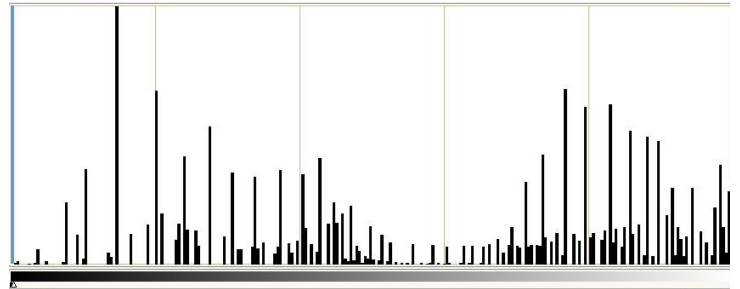


Histogram equalization reduces the brightness resolution,
i.e., the number of brightness levels actually used.

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## Histogram Equalization for Color Images

Histogram equalization can also be done for color images.

In this case it is not done per channel, of course, as this would
alter the color balance, i.e., the pixelwise ratios between two
channels (so called color shifts).

Instead, one transforms the image to HSV color space and
equalizes only the value channel.

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# Summary

- Images (or regions of images) can be described by their brightness histograms, for each brightness value counting how many pixels have this brightness.

- Low contrast often stems from non optimal use of the brightness range.

- Histogram equalization, i.e., spreading the use of the brightness values equally over the available range, can be used to make better use of the available brightness range and thus improve contrast.

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# References

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