Lecture

Image Enhancement: Spatial Domain

Image Processing

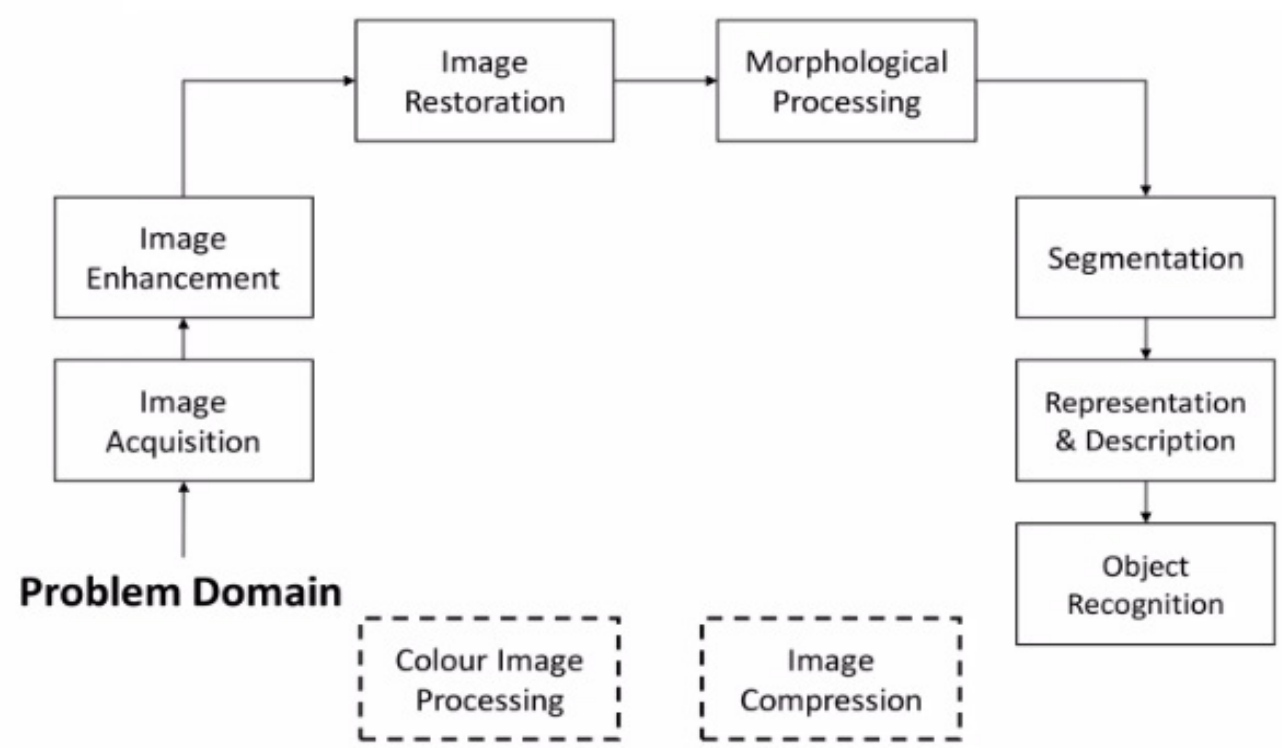


Figure 1: Image Processing

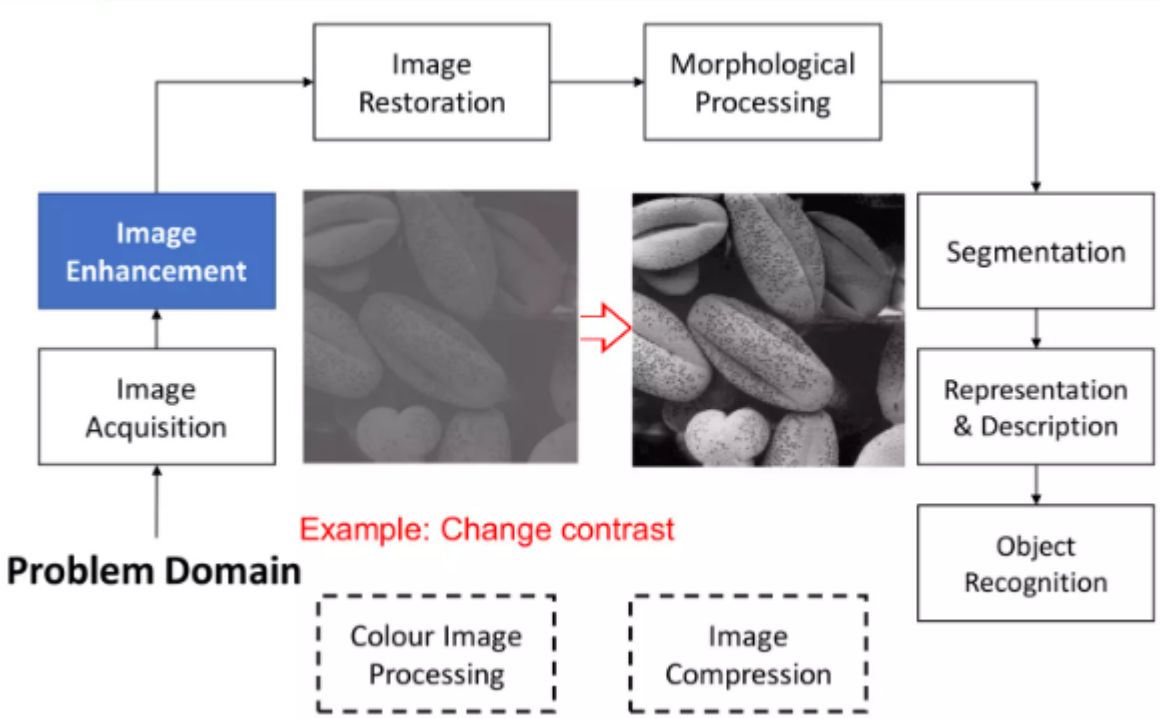
Image Enhancement

- Image enhancement is the process of manipulating an image so that the resulting image is more suitable than original image for **specific** application.

- The word specific is important here, because it establishes at the outset that enhancement technique are problem oriented.

- Providing `better' input for other automated image processing techniques

Image Enhancement



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- Image enhancement is the process of adjusting digital images so that the results are more suitable for display or further image analysis.

- For example, you can remove noise, sharpen, or brighten an image, making it easier to identify key features

Types of Image Enhancement Techniques

- Generally, a mathematical model of image degradation and its restoration is used for processing.

1. Spatial Domains Techniques
2. Frequency Domain Techniques
3. Combination Techniques

Spatial and Frequency Domains

- Spatial domain techniques manipulates the pixels of an image directly.
- This process happens in the image's coordinate system, also known as the spatial domain.
- Frequency domain techniques transforms an image from the spatial domain to the frequency domain.
- In this process, Mathematical transformations (such as the Fourier transform) are used. The image can be modified by manipulating its frequency components.

Contd..

- Most spatial domain enhancement operations can be reduced to the form

$$g(x, y) = T[f(x, y)]$$

Where,

- f (x, y) is the input image,
- g (x, y) is the processed image and
- T is some operator defined over some neighborhood of (x, y).

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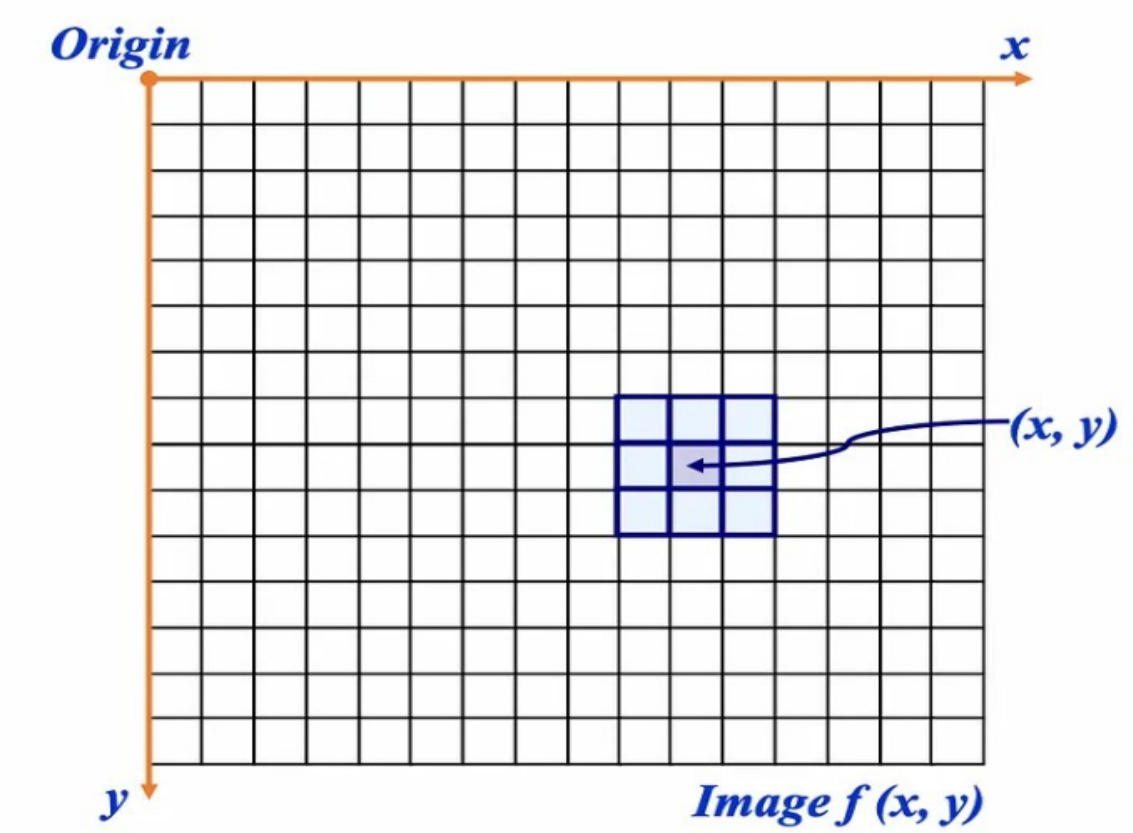

Figure 4: Spatial Image Enhancement

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- In order to process an image in the spatial domain has two basic principle-

1) Intensity transformation
2) Spatial filtering (kernel, mask, etc.)

Intensity transformation

- The general form of a spatial domain process can be expressed as:

$$G(x,y)= T(f(x,y))$$

- f(x,y): input image (original image)
- g(x,y): output image (processed image)
- T: transformation function applied to the pixel value at position

Observation

- Simplicity: Easy to understand and implement.
- Localized Effects: Can directly affect particular regions of an image.
- **Noise Sensitivity**: Point operations, especially, can be sensitive to noise.

Application

- Image Enhancement: Improving the visual quality of an image by adjusting contrast, brightness, or reducing noise.
- Edge Detection: Identifying significant transitions in intensity that correspond to object boundaries.
- Smoothing: Reducing the effects of noise or small details in the image.

Histogram Equalization

- Histogram Equalization is a technique used in image processing to improve the contrast of an image by redistributing its pixel intensity values.

- It transforms the intensity values so that they are spread across the entire range, making dark areas lighter and light areas darker.

- This method is commonly used to enhance images with poor contrast, making them visually clearer and more informative.

Introduction to Image Histograms

- An image histogram is a graphical representation that shows the distribution of pixel intensity values in a digital image.

- It provides insight into the contrast, brightness, and intensity distribution of an image, which are critical for tasks like image enhancement, thresholding, and segmentation.

Introduction to Image Histograms

- They are particularly useful in the domains of image translation, image retrieval, grayscale threshold segmentation of images, and image classification.

- It widely used because of their cheap computing cost and many other advantages, such as invariance to image translation, rotation, and scale.

Definition of a Histogram

- In an image, pixel values typically range from 0 (black) to 255 (white) for grayscale images.
- A histogram plots the number of pixels (frequency) for each intensity value.

Histogram Representation

- X-axis: Represents the possible pixel intensity values (0 to 255 for an 8-bit grayscale image).
- Y-axis: Represents the frequency or number of pixels corresponding to each intensity value.

Consider following matrix and plot a Histogram of an image

$$\begin{bmatrix} 3 & 6 & 6 & 8 \\ 5 & 3 & 1 & 4 \\ 8 & 6 & 5 & 1 \\ 4 & 8 & 2 & 3 \end{bmatrix}$$

Method 1:

In this method, the x-axis has grey levels/ Intensity values and the y-axis has the number of pixels in each grey level.

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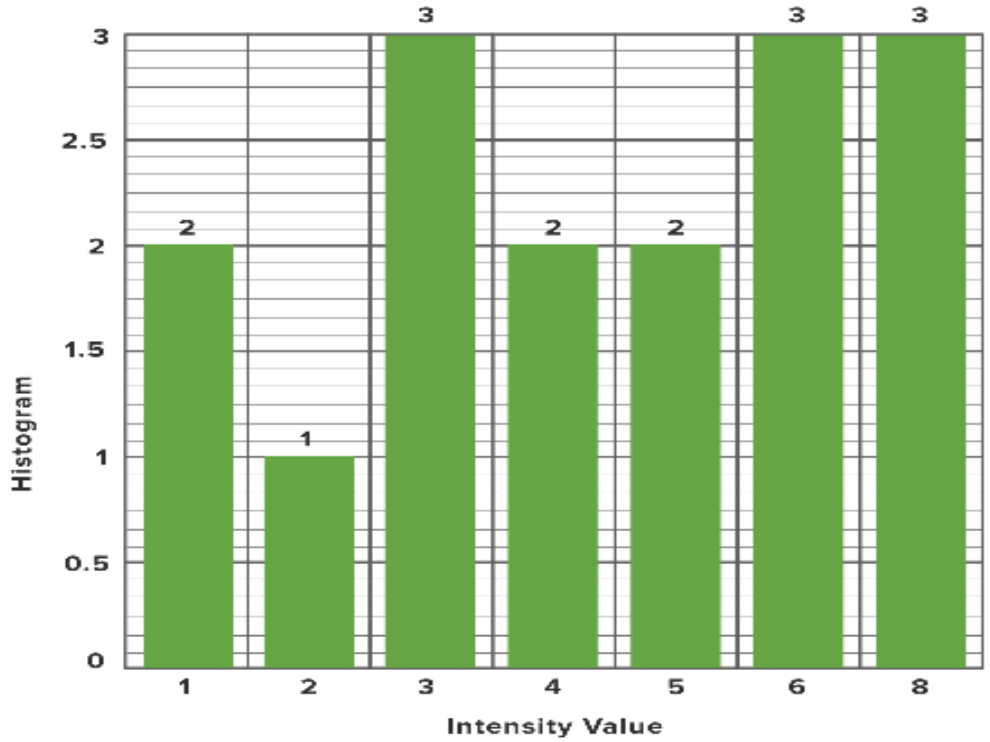

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Method 2:

- Use concept of probability function.
- In this method, the x-axis represents the grey level, while the y-axis represents the probability of occurrence of that grey level.

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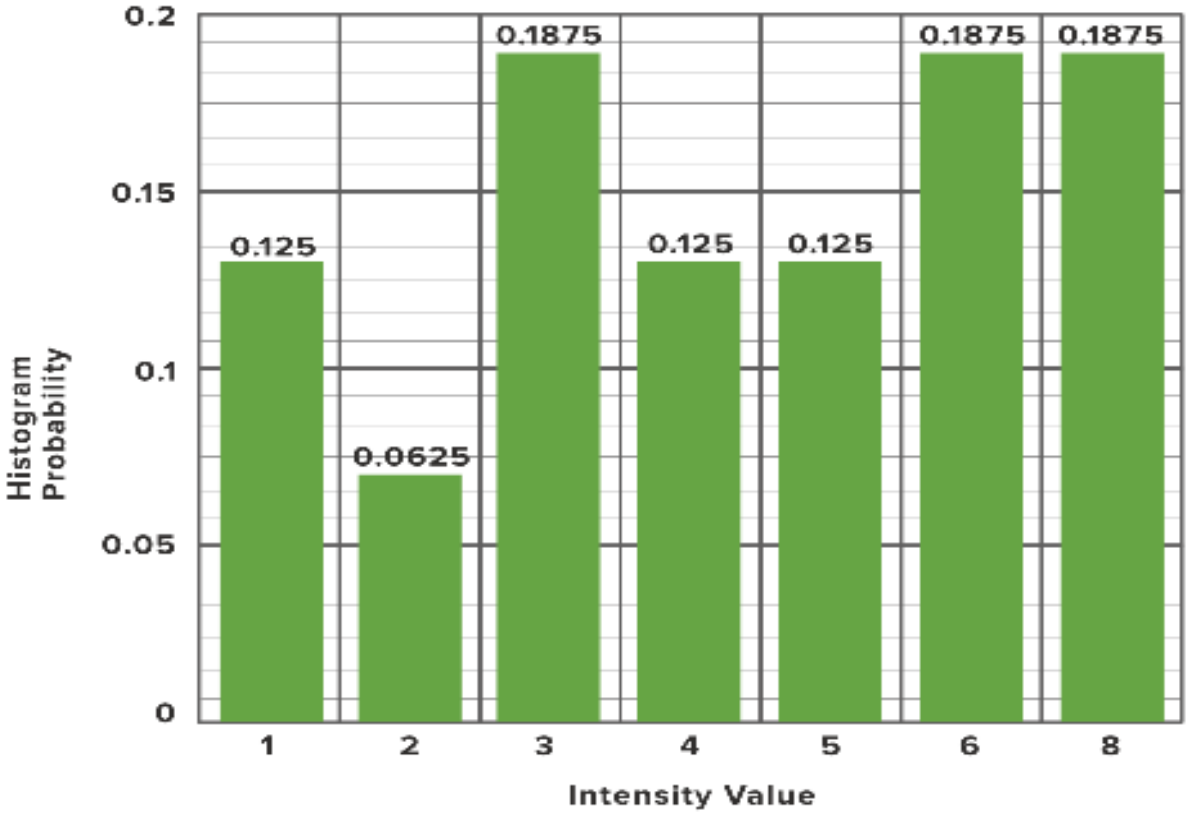
Intensity Value/ Gray Level	#/Occurrence of intensity value/ number of pixels	Probability
1	2	0.125
2	1	0.0625
3	3	0.1875
4	2	0.125
5	2	0.125
6	3	0.1875
8	3	0.1875

Contd..


0.2
0.15
0.1
0.05
0
Histogram Probability
0.125
0.0625
0.1875
0.125
0.125
0.1875
0.1875
1
2
3
4
5
6
8
Intensity Value

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Grey Image

Number of pixel intensities = 256

0 → Black

255 → White

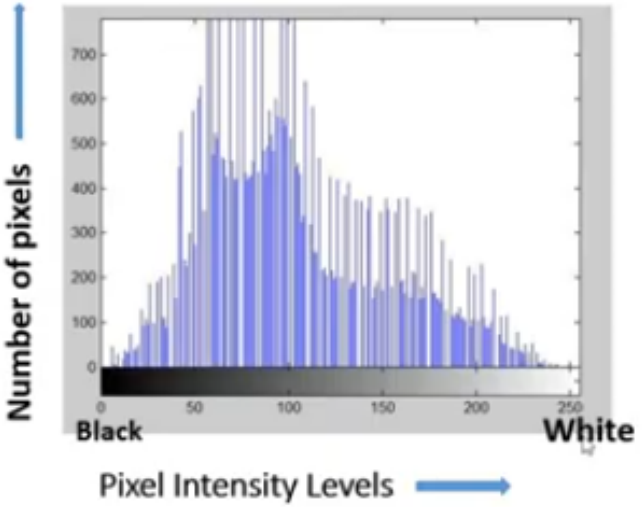
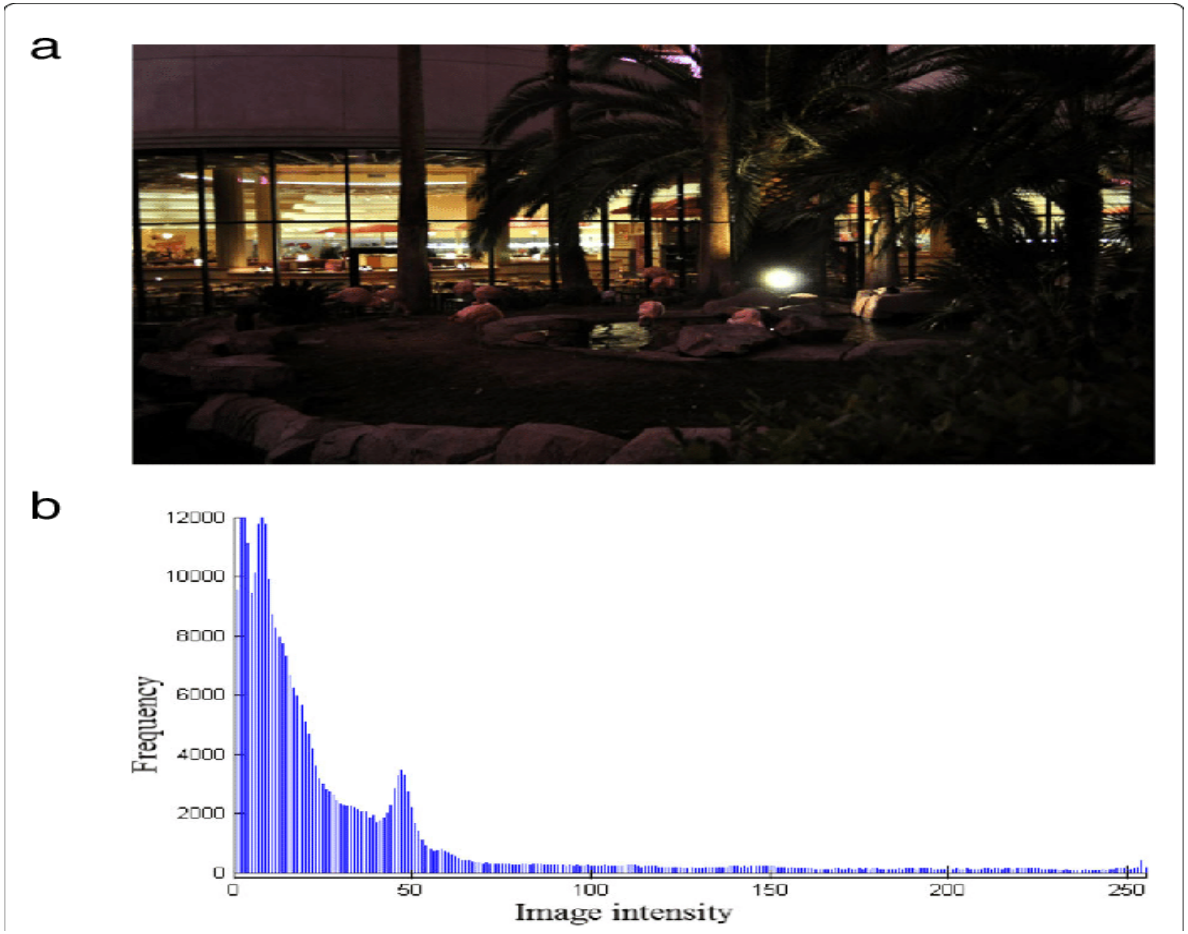
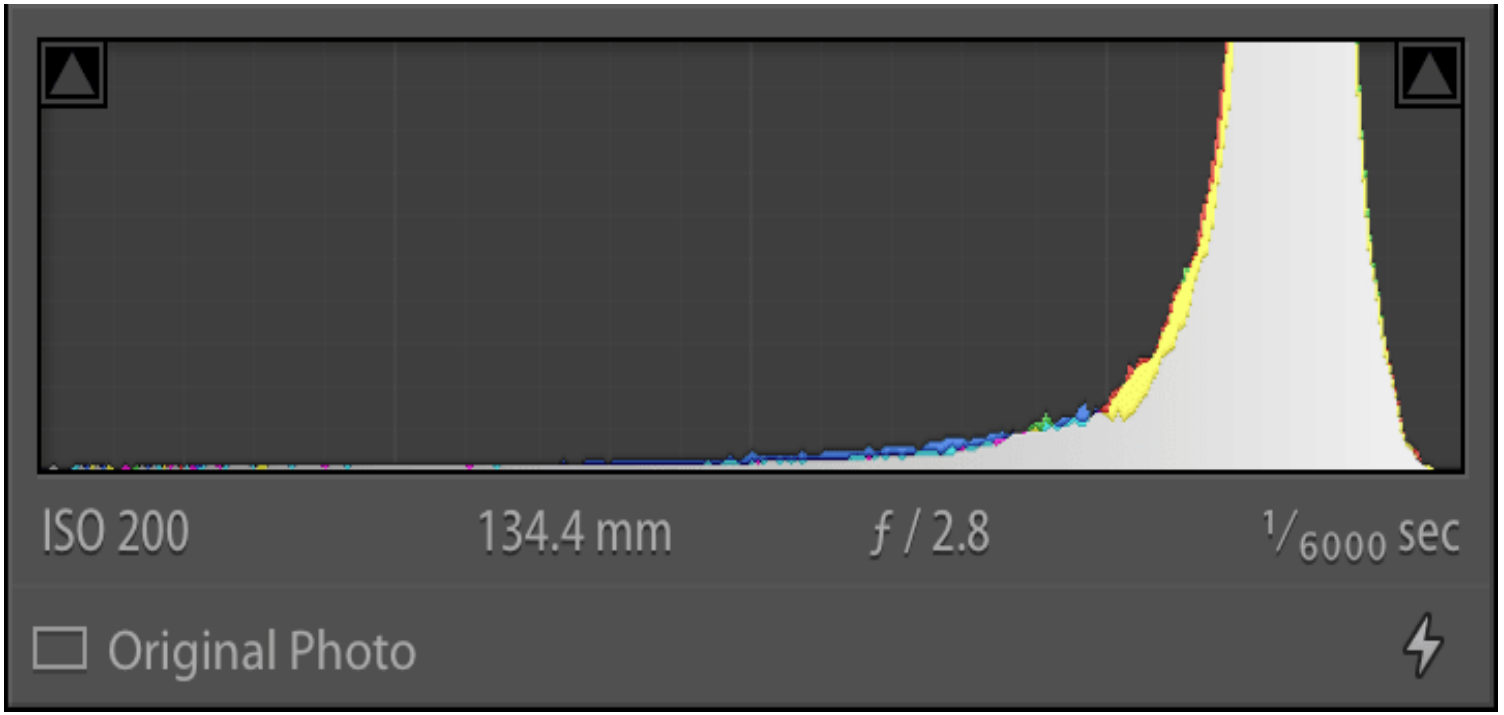


Image Histogram of dark image



Bright image

Image Histogram of bright image



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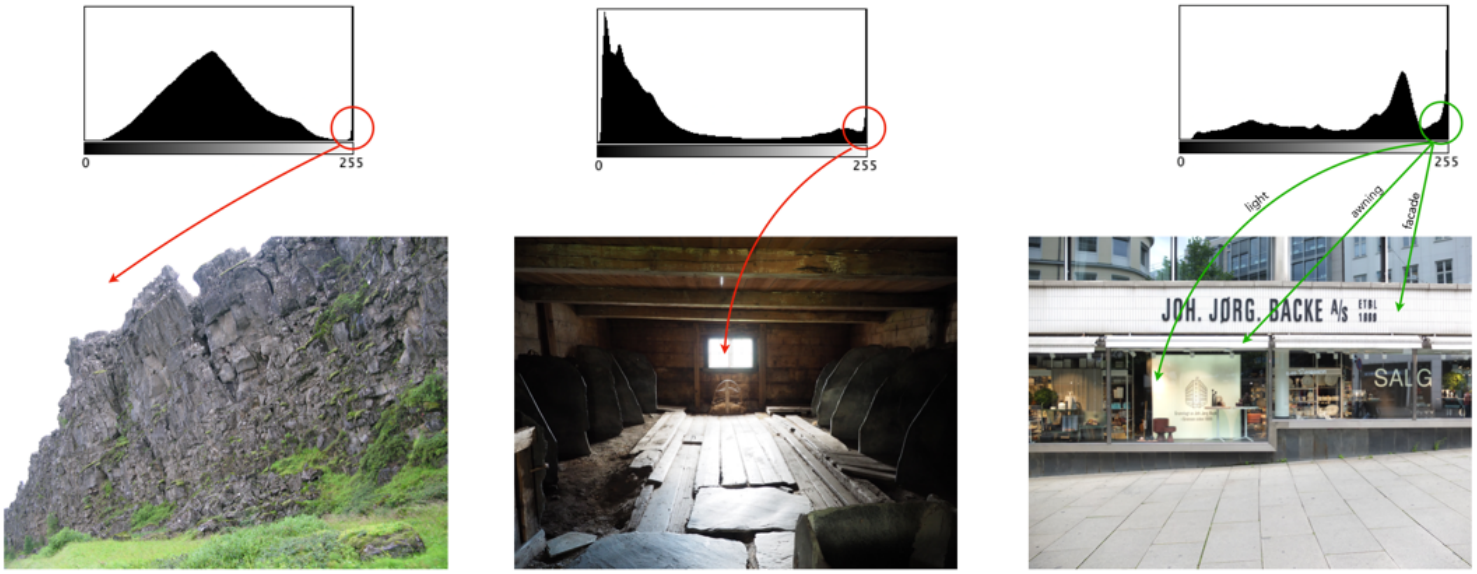
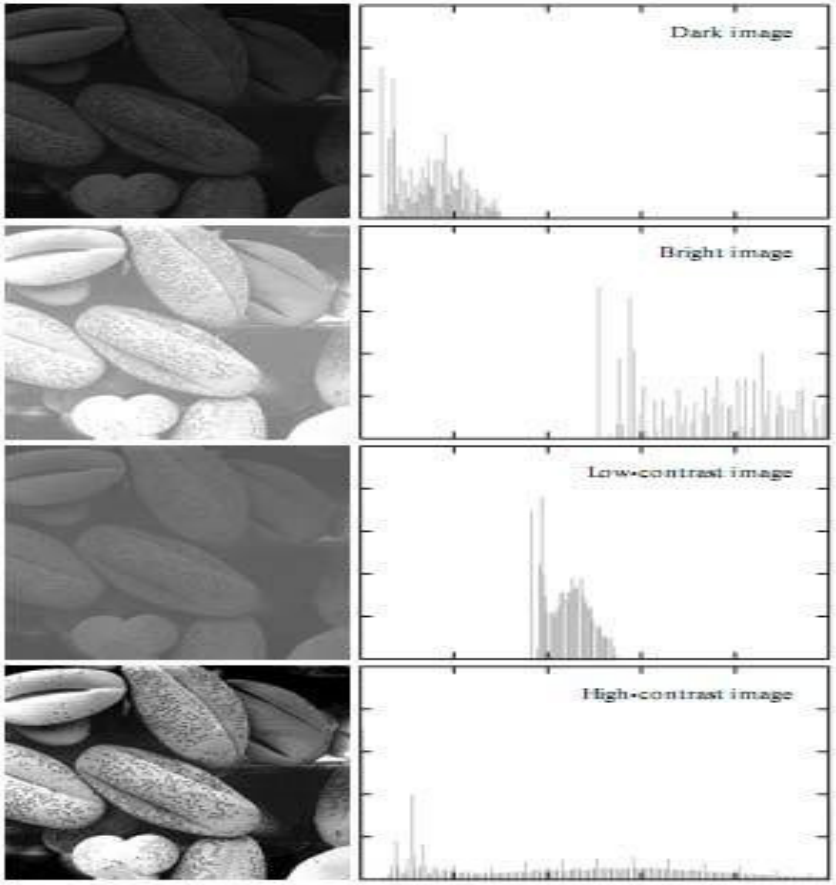


blown-out overcast sky

overexposed light from window

white objects in the scene

Contd..


Dark image
Bright image
Low-contrast image
High-contrast image

Histogram equalization

- Histogram equalization is used for equalizing all the pixel values of an image. Transformation is done in such a way that uniform flattened histogram is produced.

- Histogram equalization increases the dynamic range of pixel values and makes an equal count of pixels at each level which produces a flat histogram with high contrast image.