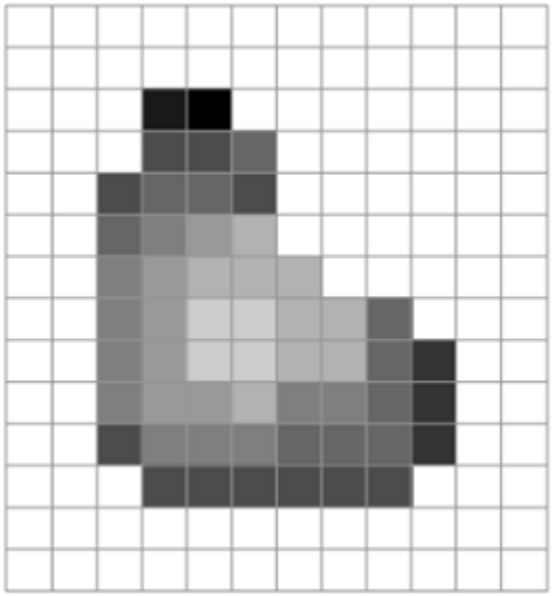
# Introduction

- An image is a projection of a 3D scene into a 2D projection plane.
- An image can be defined as a 2-D light intensity function f(x, y).
- An digital image f(x,y) is discretized both in spatial coordinates and brightness.
- It can be considered as a matrix whose row, column indices specify a point in the image and the element value identifies gray level value at that point.
- These elements are referred to as pixels.

# Image Sampling and Quantization

- Sampling – Digitizing coordinate values
- Quantization – Digitizing amplitude values



( a) Result of image sampling and quantization

# Image Enhancement

- Processing an Image to enhance certain features of the image
- The result is more suitable than the original image for certain specific applications
- Processing techniques are very much problem oriented. For example, Best technique for enhancement of X-ray image may not be the best for enhancement of microscopic images

# Different Enhancement Techniques

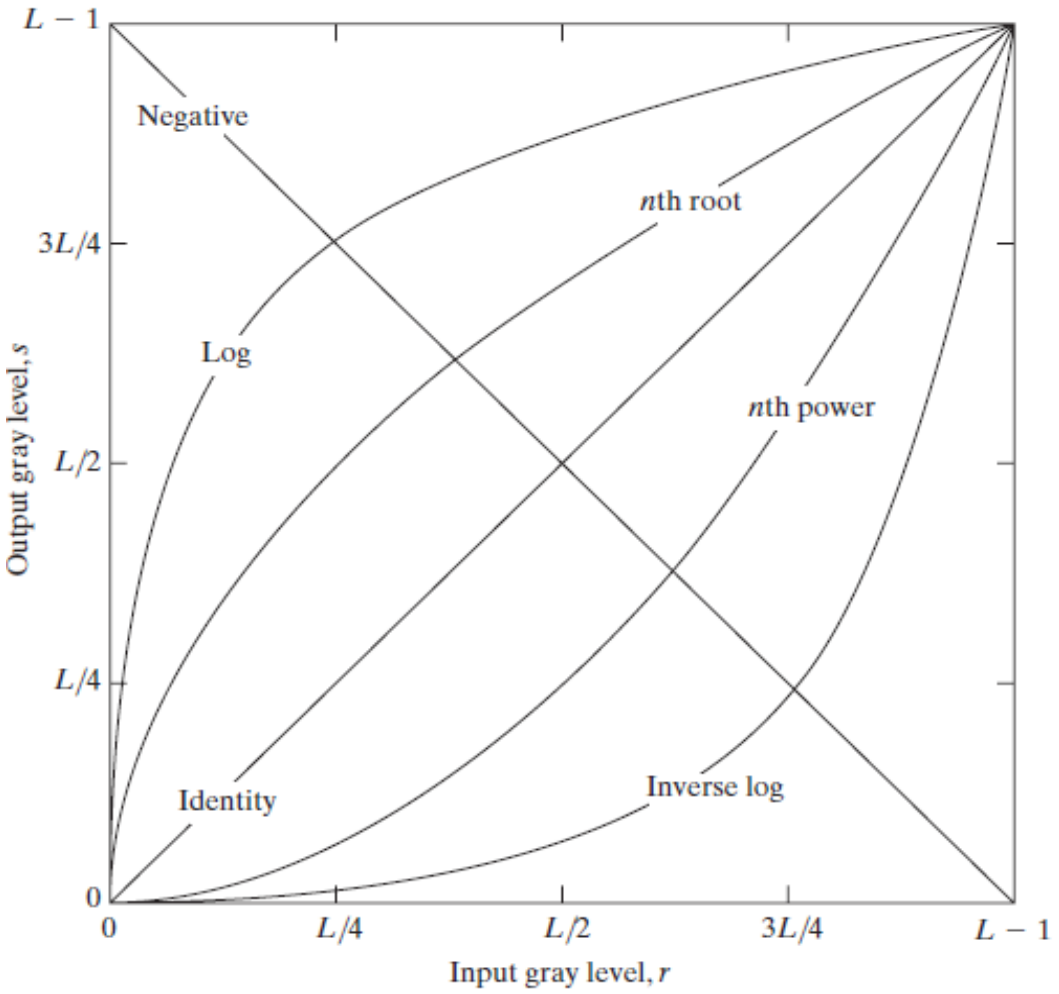
- Enhancement techniques fall under two broad categories
- Spatial Domain Technique
  - Work on Image Plane itself
  - Direct manipulation of pixels in an image
- Frequency Domain Technique
  - Modify Fourier Transform coefficients of an image
  - Take inverse Fourier Transform of the modified coefficients to obtain the enhanced Image.

# Gray level transformations for image enhancement

Expression: s = T(r);
T = transformation that maps pixel value r into pixel value s.

3 types:

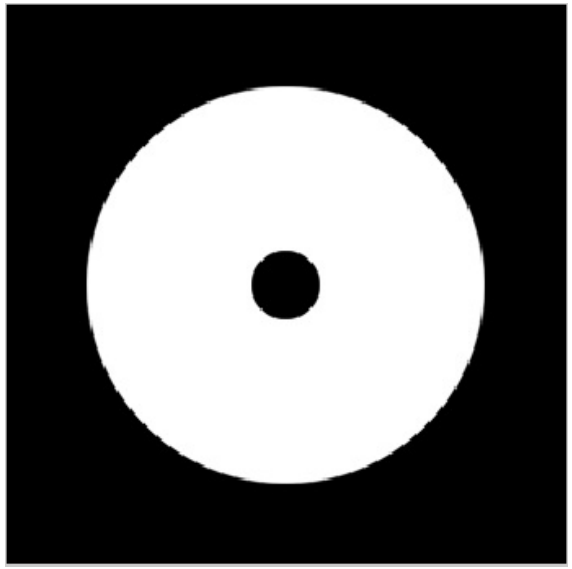
- Linear: negative and identity
- Logarithmic: log and inverse-log
- Power: $n^{th}$ power and $n^{th}$ root



# Image Negative

Operation: Reversing intensity levels

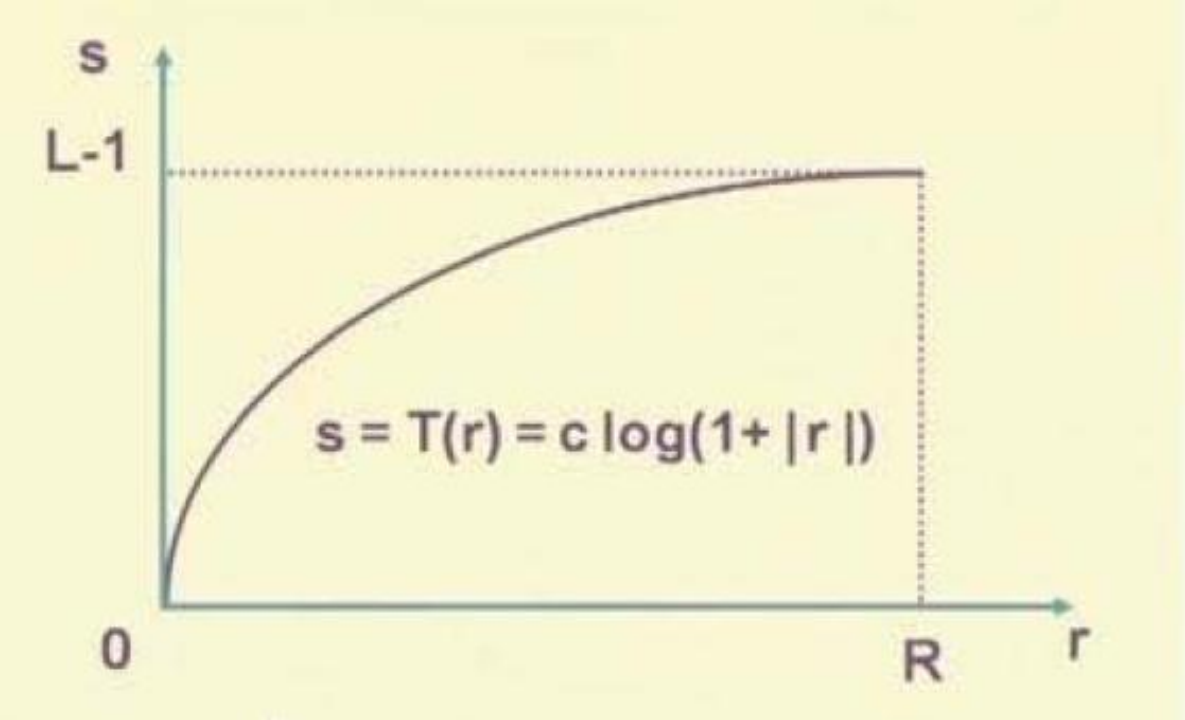
Application: Enhancing white or gray detail embedded in dark regions.



# Log transformation

Expression: $s = c \log(1+r)$; $c = \text{const}, r \geq 0$

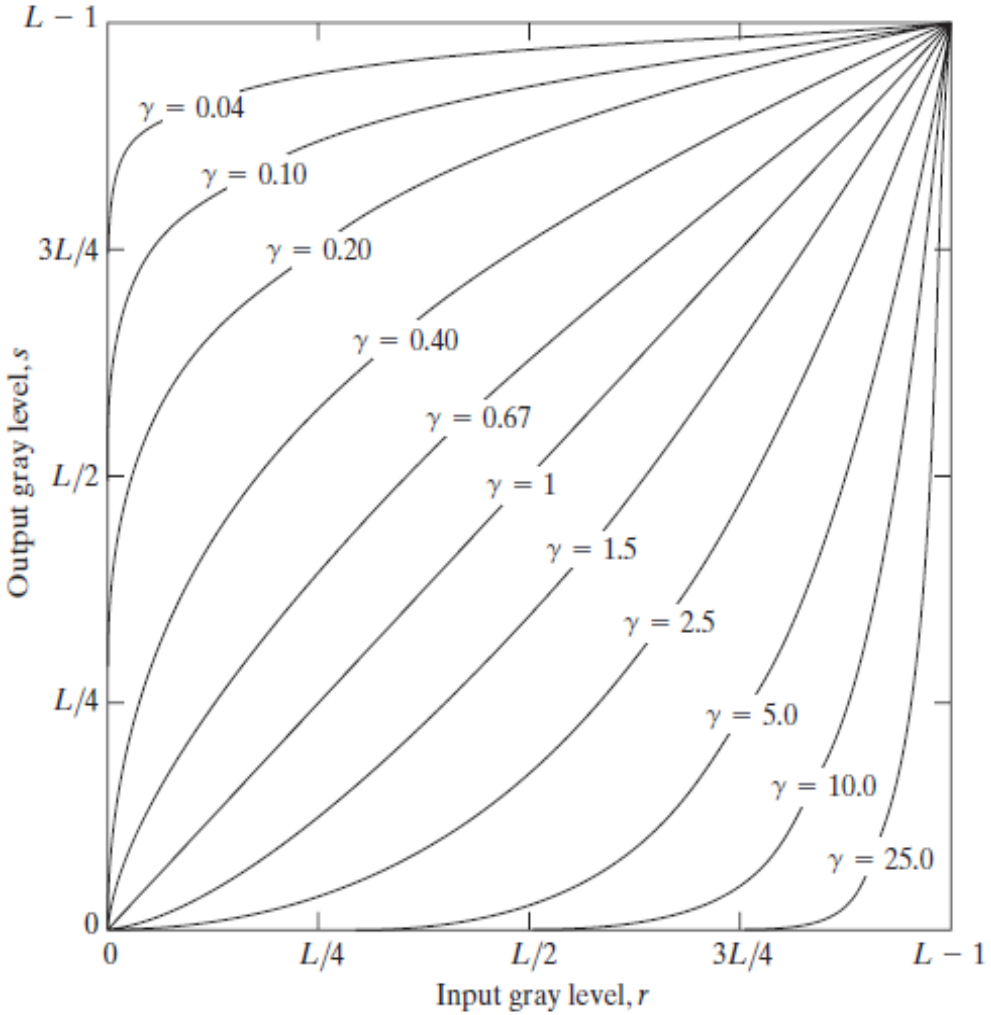
Applications: Dynamic Range Compression



# Power-Law transforms

Expression: $s = c\, r^{\gamma}$

Operation: fractional values of γ map a narrow range of dark input values into a wider range of output values; opposite for γ > 1



# Power-Law transforms

For $\gamma < 1$, produce images that are lighter.

a) Input image
b) Output image with $\gamma = 0.1$

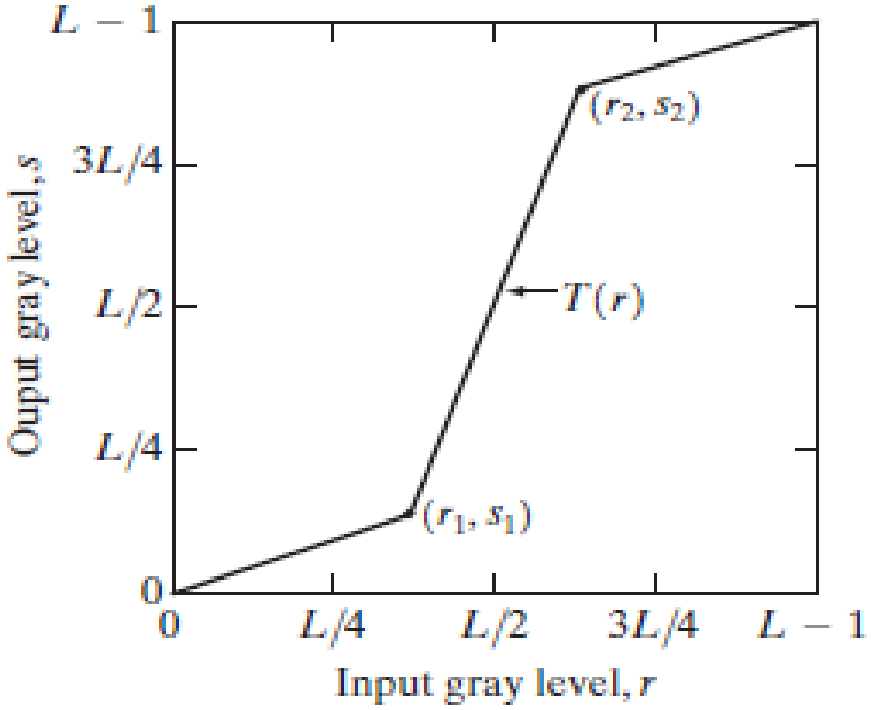
# Power-Law transforms

For $\gamma > 1$, produce images that are darker

a) Input image
b) Output image with $\gamma = 2.5$

# Contrast stretching

Operation: Locations of points (r1, s1) and (r2, s2) control the shape of the transformation function



# Result of Contrast Stretching

# Histogram

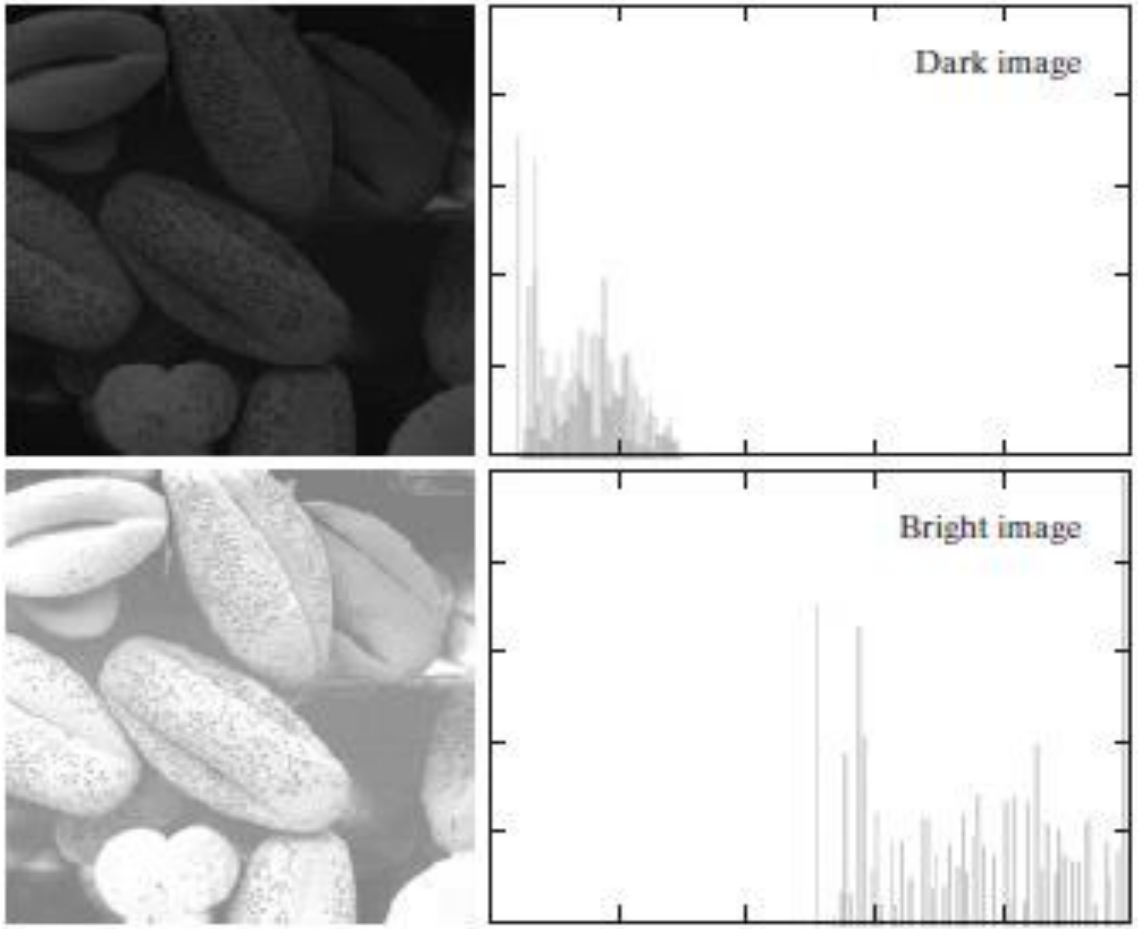
The histogram of a digital image with gray levels in the range [0, L-1] is a discrete function

$$h(r_k) = (n_k) , \quad k=0,1,\ldots\ldots .,L-1$$

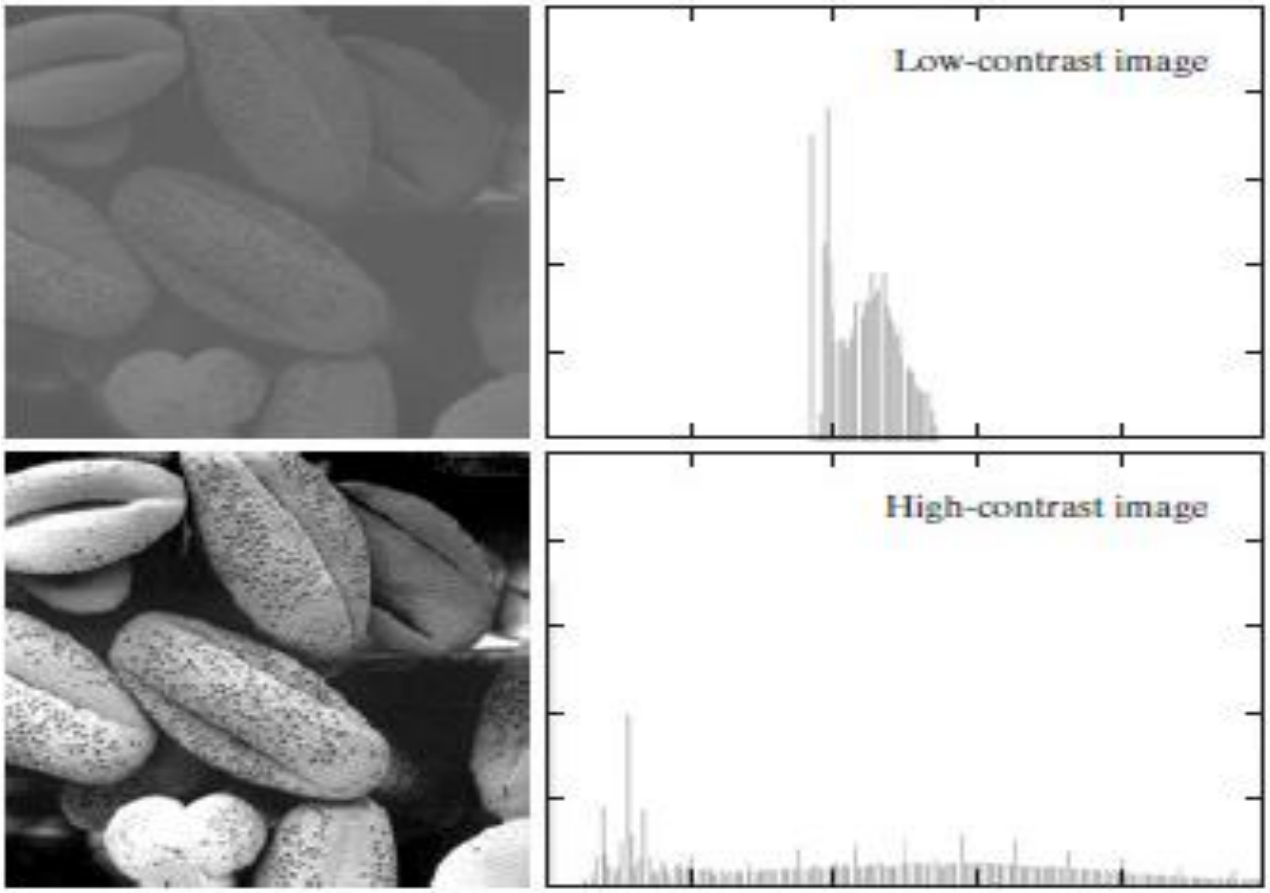
$r_k$ = kth gray level and $n_k$ = number of pixels in the image having gray level $r_k$

normalized histogram: $p(r_k) = (n_k) / n$

# Histogram



# Histogram

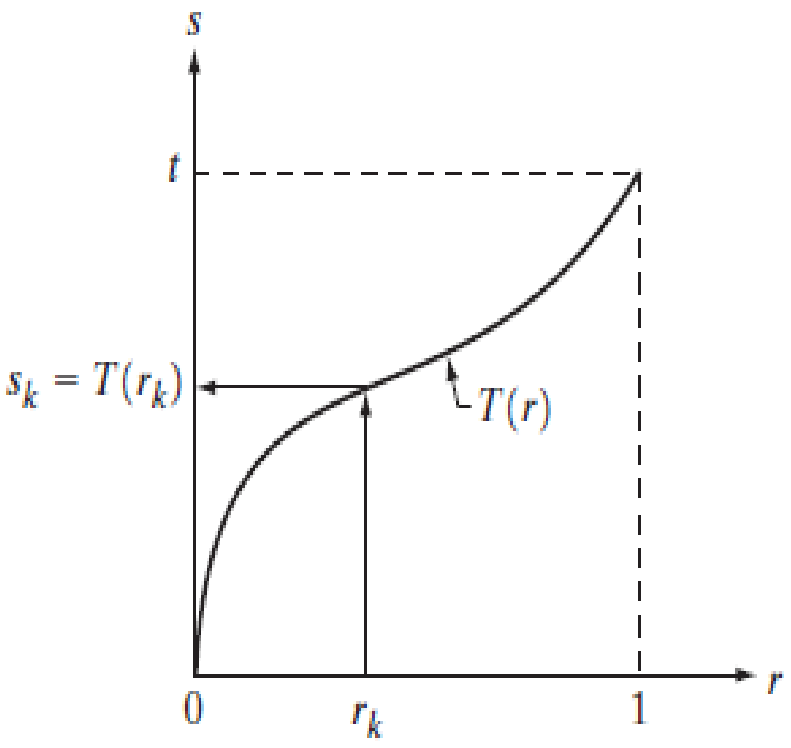


# Histogram equalization

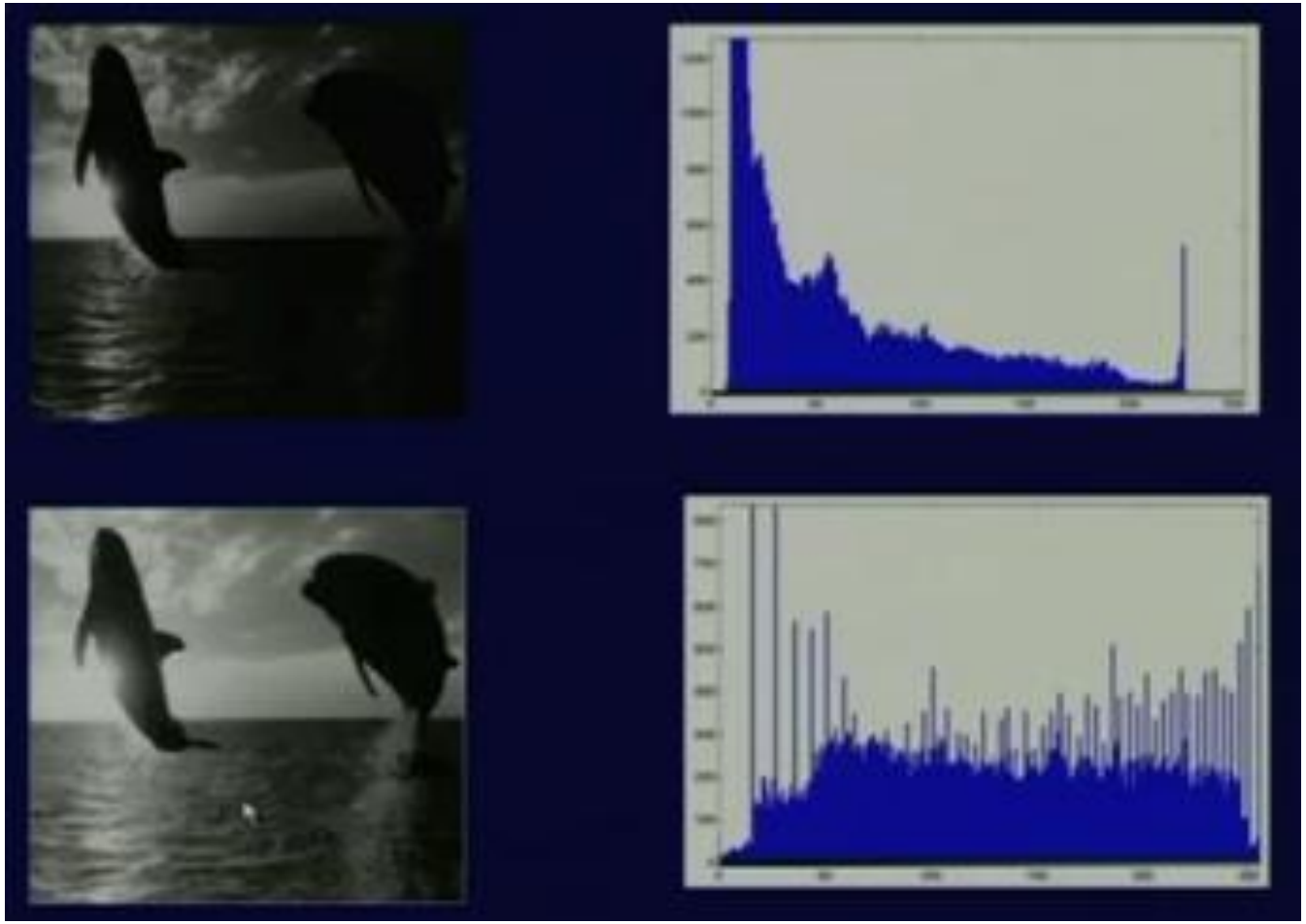
$$s = T(r), \qquad 0 \le r \le 1$$

Used for enhancing the contrasts in an image

- Through this, the intensities are better distributed on the histogram
- Application: useful in images with backgrounds and foregrounds that are both bright or both dark



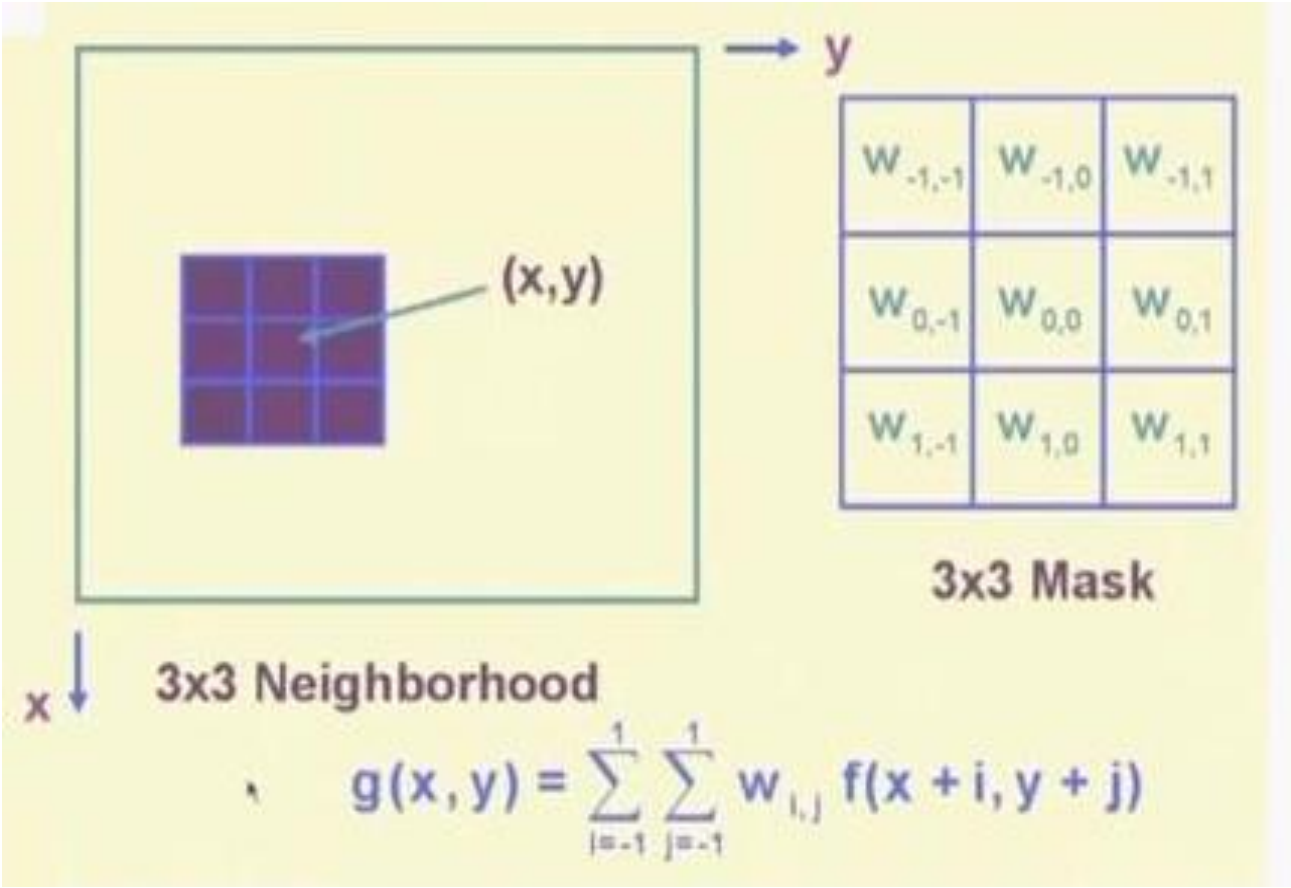
# Histogram equalization



# Spatial filtering

- Filtering operations that are performed **directly on the pixels** of an image
- Spatial filtering involves the convolution of an image with a specific kernel operator.
- The gray level of each pixel is replaced with a new value that is the weighted average of neighboring pixels that fall within the window of the kernel.
- If the operation performed on the image pixels is linear, then the filter is called linear spatial filter, otherwise it is called non-linear filter.

# Mask Processing

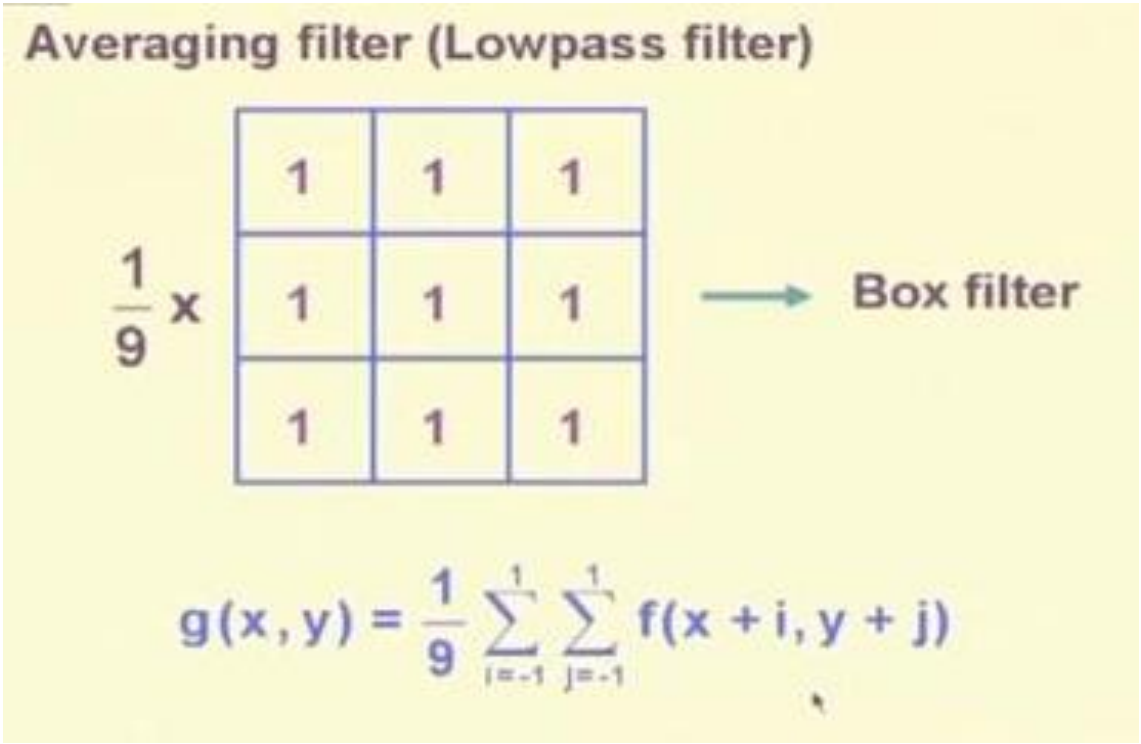


# Mask Processing techniques

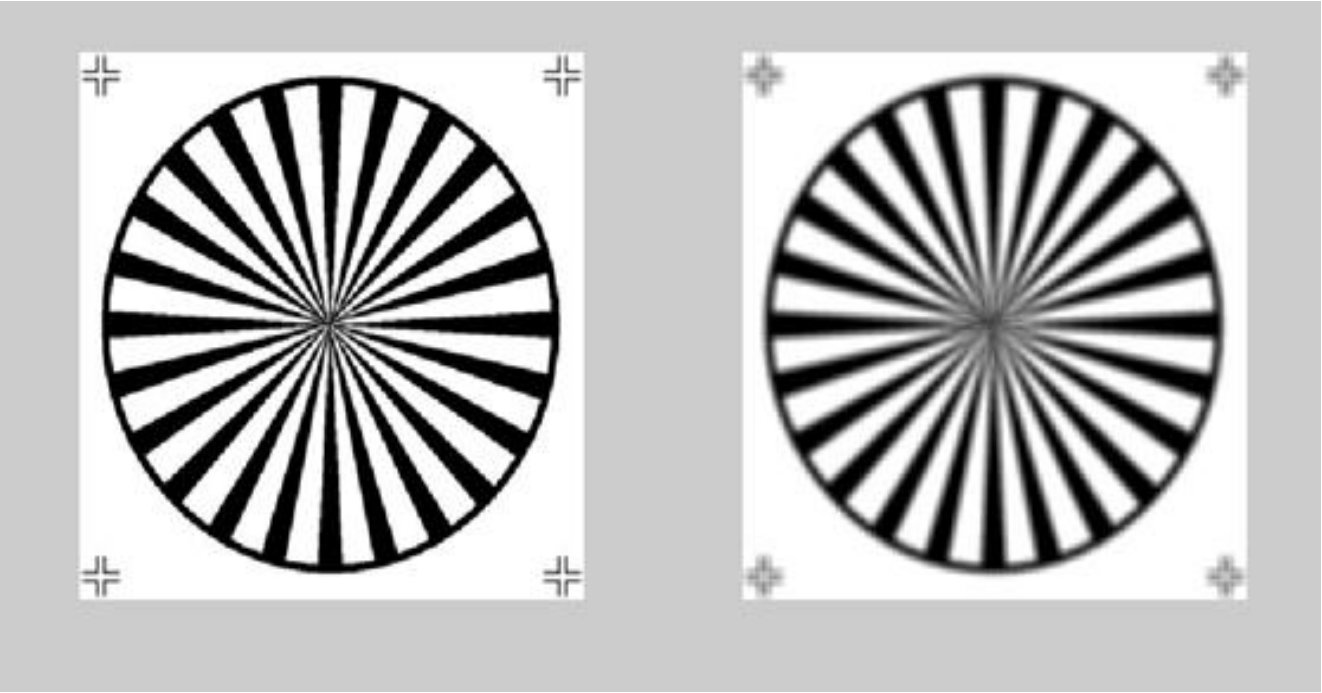
- Linear smoothing filter
- Median Fitter (nonlinear)

# Smoothing Spatial Filters

- Used for blurring and for noise reduction
- The output (response) is the average of the pixels contained in the neighborhood of the filter mask



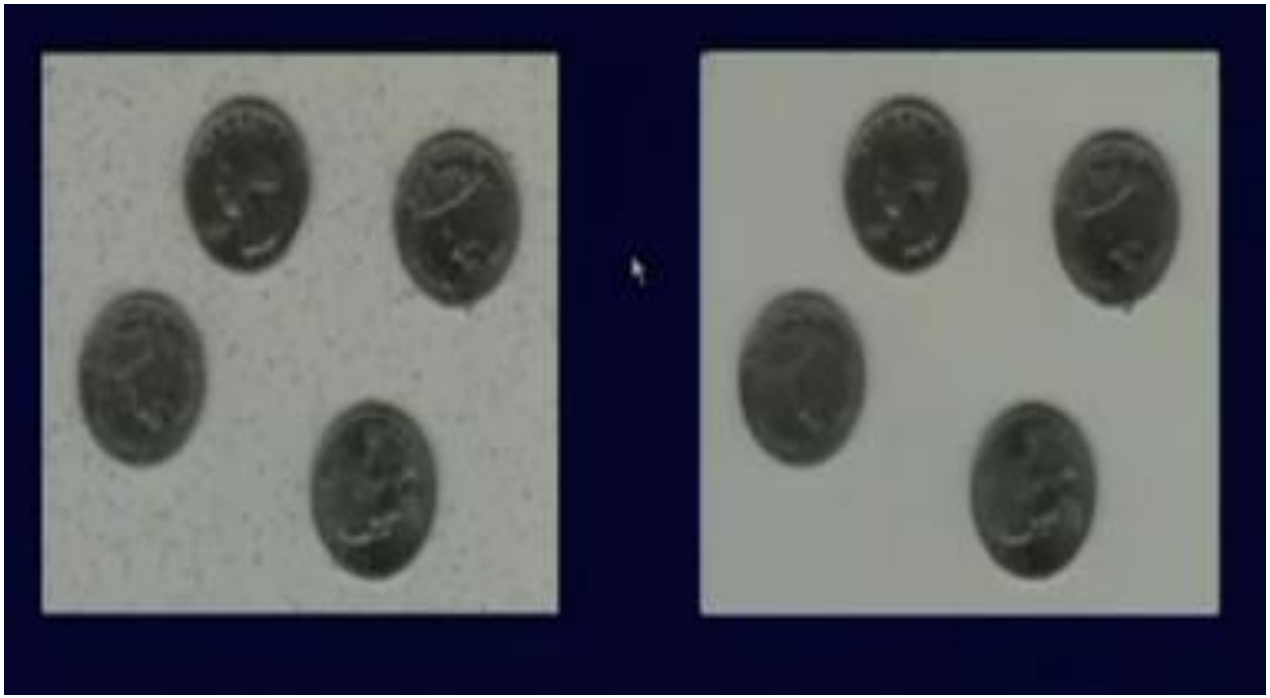
# Smoothing Spatial Filters



# Nonlinear spatial filters
# Order-Statistics Filters

- **Median filter** - Replaces the value of a pixel by the median of the gray levels in the neighborhood of that pixel
- Provide excellent noise-reduction capabilities, with considerably less blurring than linear smoothing filters of similar size.
- Particularly effective in the presence of salt-and-pepper noise

# Median filter



# Median filter