Digital Image Processing and Pattern Recognition

E1528

Fall 2022-2023

Lecture 3

Intensity Transformations and Spatial Filtering

INSTRUCTOR

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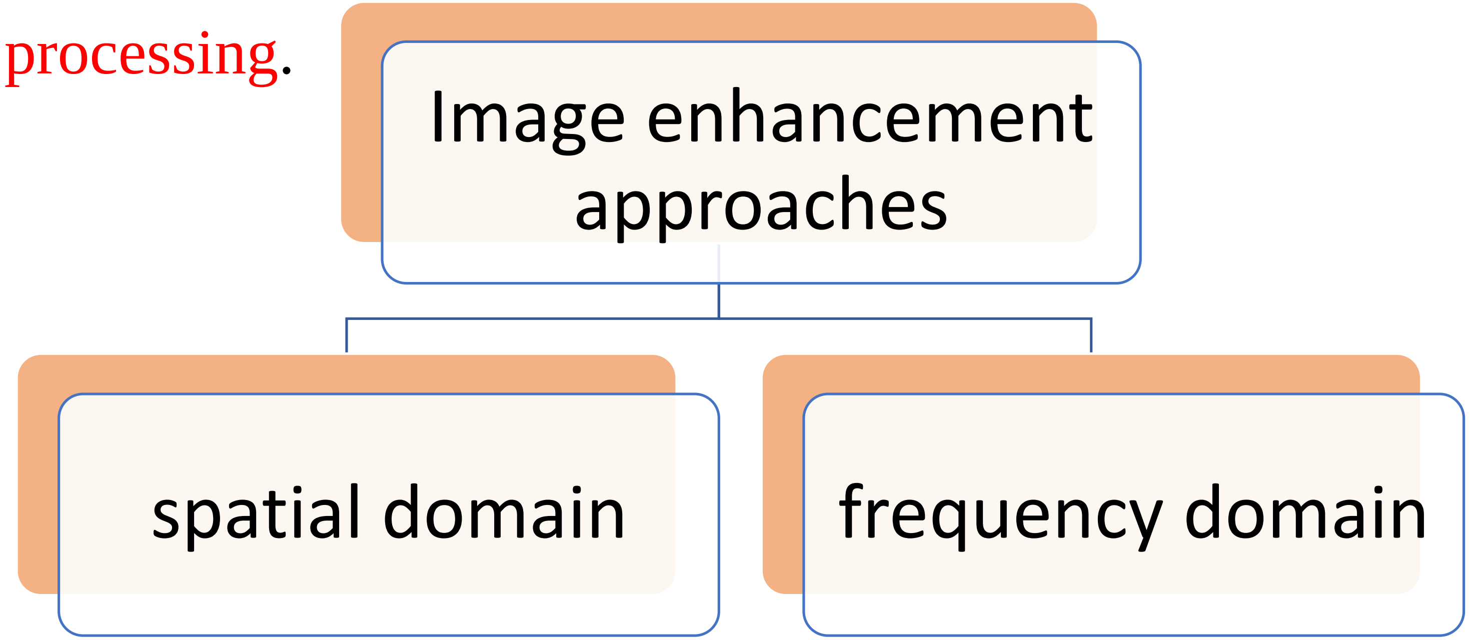
➢ Some Basic Gray Level Transformations

- The principal objective of enhancement is to process an image so that the result is more suitable than the original image for a specific application.

- Image enhancement is one of the most interesting and visually appealing areas of image processing.



Spatial domain Vs. Frequency domain

- The term spatial domain refers to the image plane itself, and approaches in this category are based on direct manipulation of pixels in an image.

- Frequency domain processing techniques are based on modifying the Fourier transform of an image.

- There is no general theory of image enhancement.

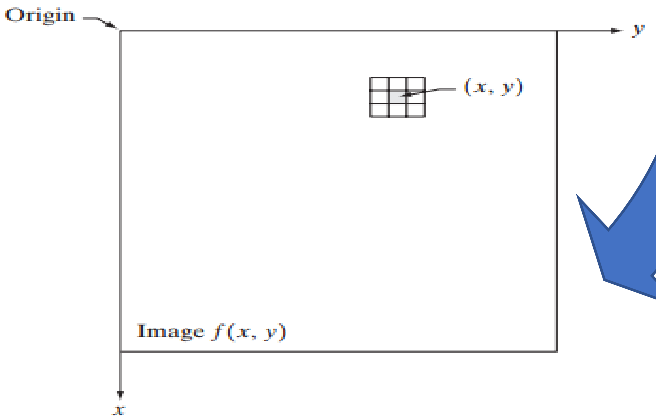
➢ Background

- ➢ Spatial domain processes will be denoted by the expression

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

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

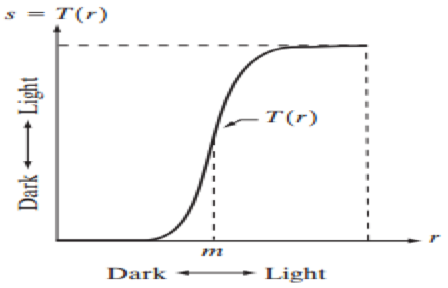
In addition, T can operate on a set of input images, such as performing the pixel-by-pixel sum of K images for noise reduction

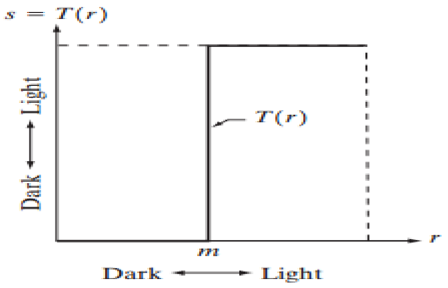


Background

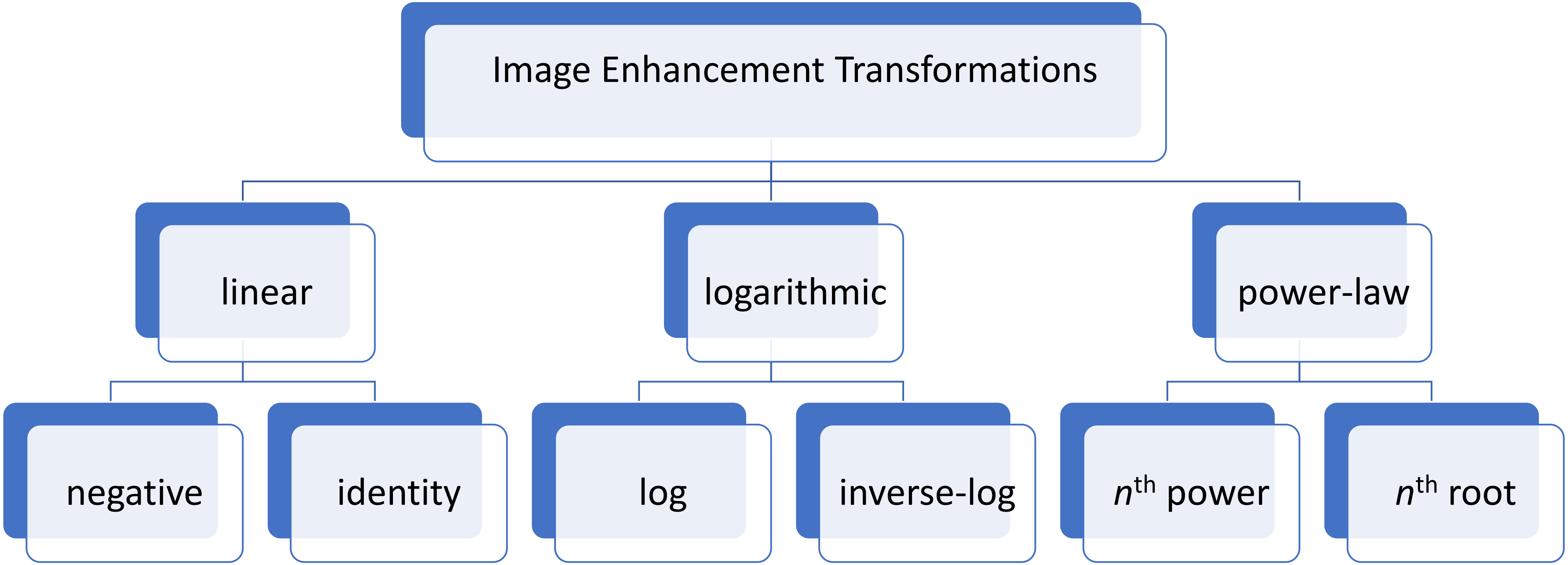
- The simplest form of T is when the neighborhood is of size 1*1 (that is, a single pixel). In this case, g depends only on the value of f at (x, y), and T becomes a gray-level (also called an intensity or mapping) transformation function of the form $s = T(r)$

- where, for simplicity in notation, r and s are variables denoting, respectively, the gray level of f(x, y) and g(x, y) at any point (x, y).



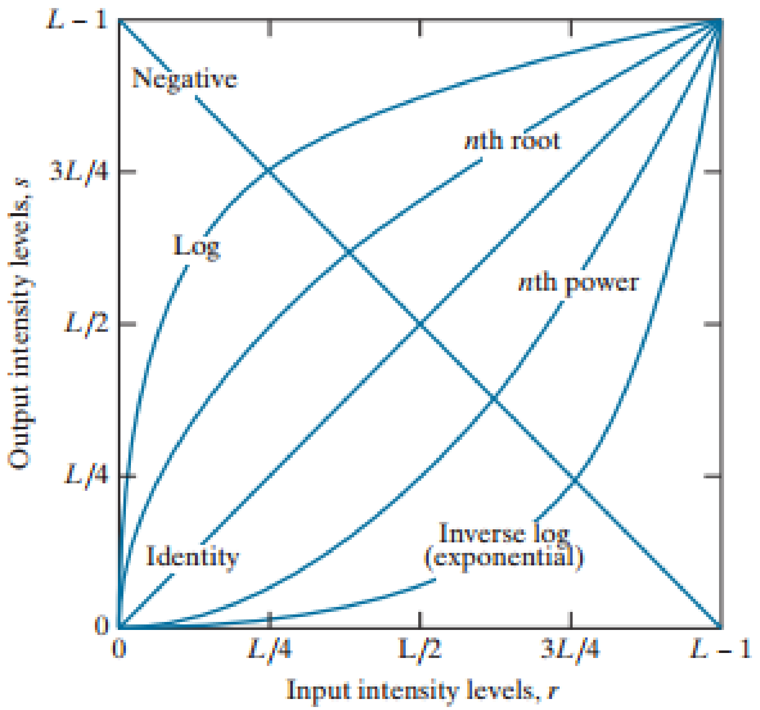


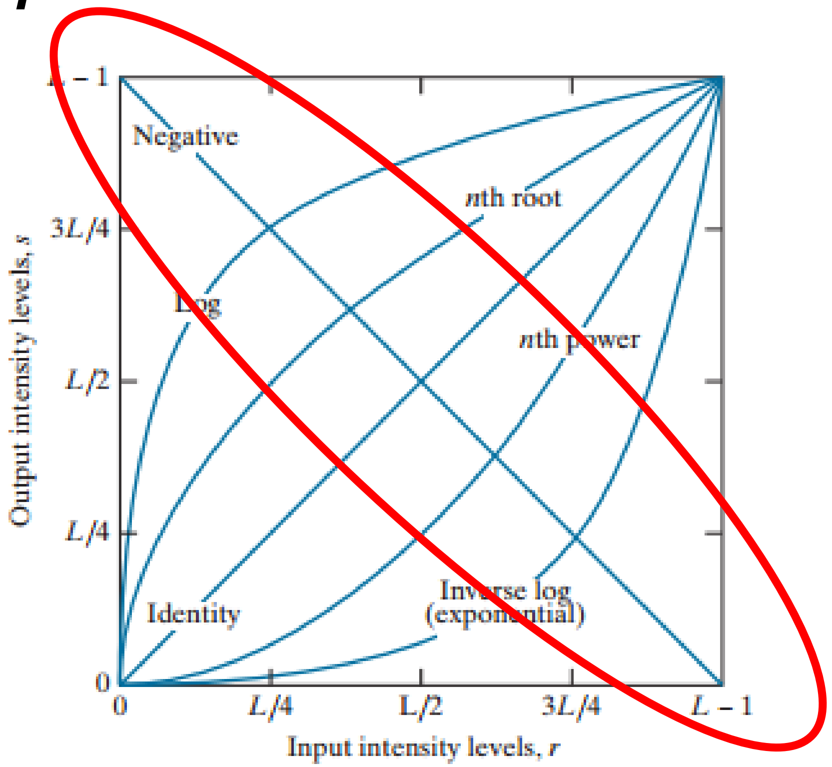
➢ Some Basic Gray Level Transformations



➢ Linear - Image Negatives

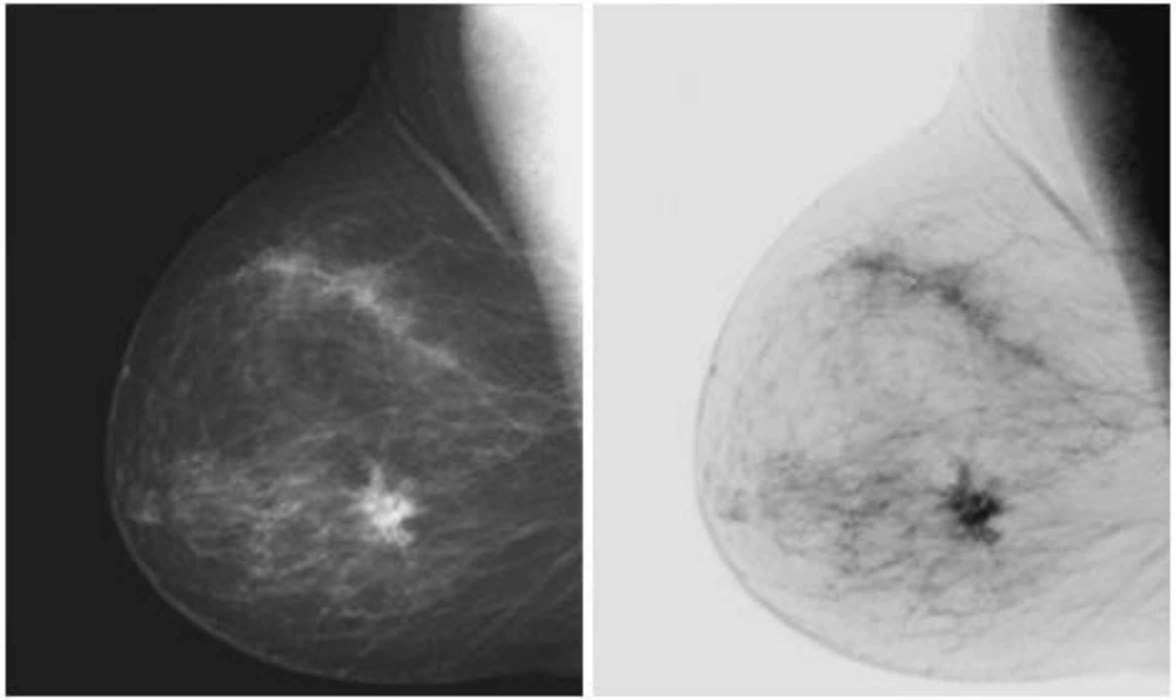
- The negative of an image with gray levels in the range [0, L-1] is obtained by using the negative transformation shown below, which is given by the expression $s = L - 1 - r$





Linear - Image Negatives

- The original image is a digital mammogram showing a small lesion. Although the visual content is the same in both images,
- Note how much easier it is to analyze the breast tissue in the negative image in this case.



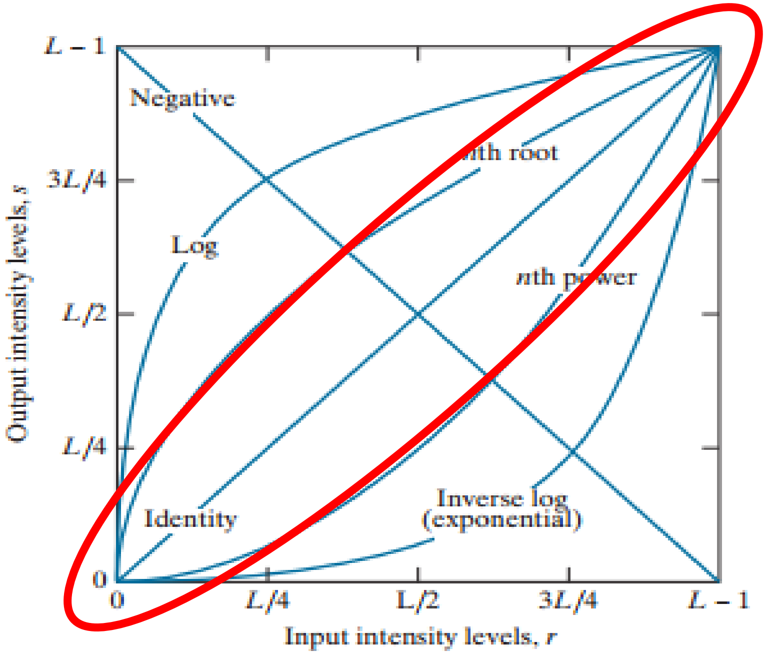
a b

(a) Original digital mammogram. (b) Negative image obtained using the negative transformation in

➢ Linear - Image identity

- ➢ The identity function is the trivial case in which output intensities are identical to input intensities.

- ➢ It is included in the graph only for completeness.



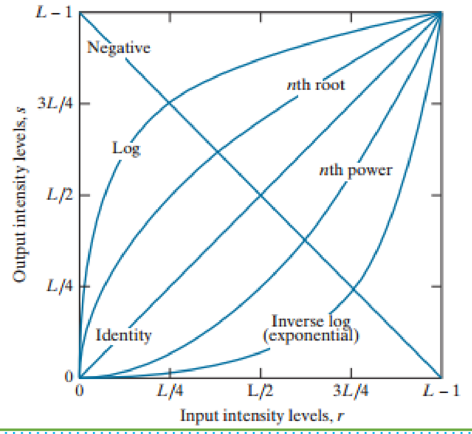
Log Transformations

- The general form of the log transformation is

$$s = c \log(1 + r)$$

where c is a constant, and it is assumed that r >= 0.

- The shape of the log curve in Fig. below shows that this transformation maps a narrow range of low gray-level values in the input image into a wider range of output levels.

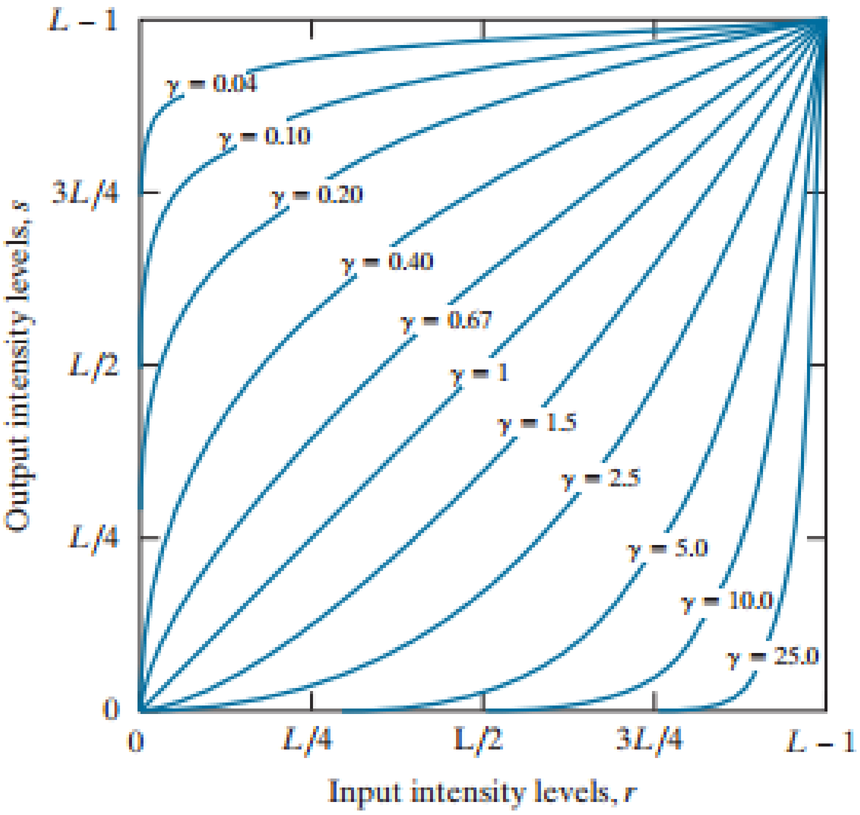


➢ Power-Law Transformations

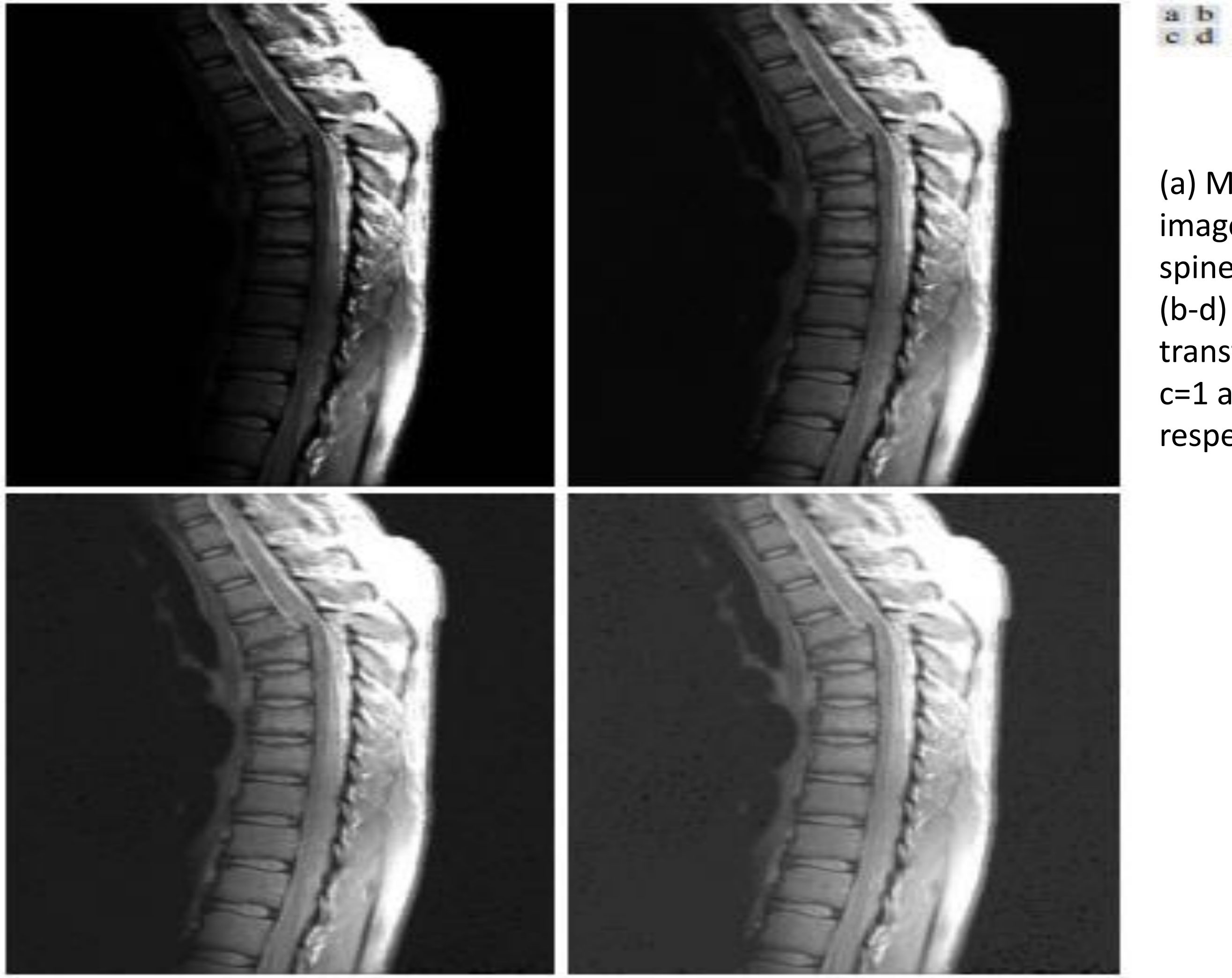
- ➢ Power-law transformations have the basic form

$$s = cr^{\gamma}$$

where c and γ are positive constants. Sometimes this Eq. is written as $s = c(r + \varepsilon)^{\gamma}$ to account for an offset (that is, a measurable output when the input is zero).



➢ Power-Law Transformations Example



(a) Magnetic resonance (MR) image of a fractured human spine.
(b-d) Results of applying the transformation in equation with c=1 and γ=0.6, 0.4 and 0.3 respectively.

➢ Power-Law Transformations Example

a b
c d

(a) Aerial image.
(b-d) Results of applying the transformation in equation with c=1 and γ=3, 4, and 5 respectively.

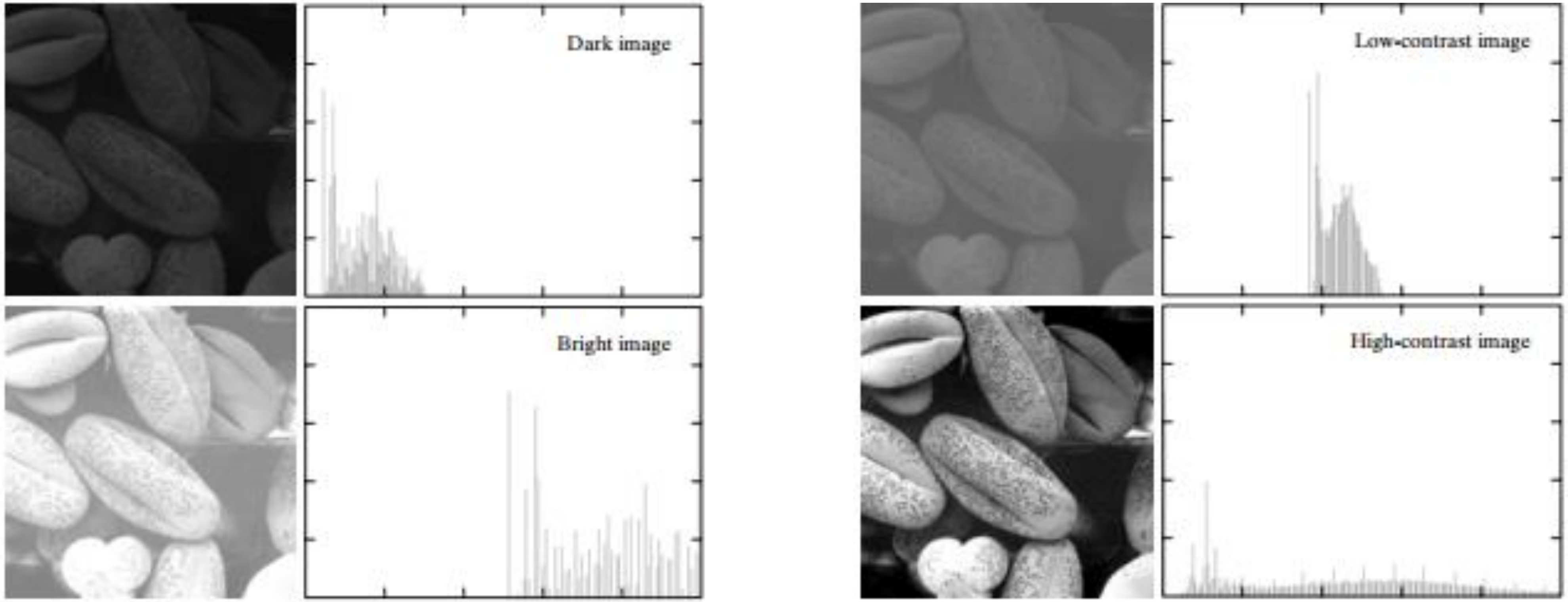
Histogram Processing

- The histogram of a digital image with gray levels in the range [0, L-1] is a discrete function $h(r_k)=n_k$, where r_k is the k_{th} gray level and n_k is the number of pixels in the image having gray level r_k.
- It is common practice to normalize a histogram by dividing each of its values by the total number of pixels in the image, denoted by n.
- Thus, a normalized histogram is given by $p(r_k)=n_k/n$, for $k=0, 1, \ldots, L-1$.
- Loosely speaking, $p(r_k)$ gives an estimate of the probability of occurrence of gray level r_k. Note that the sum of all components of a normalized histogram is equal to 1.

Histogram Processing

- Histograms are the basis for numerous spatial domain processing techniques.
- Histogram manipulation can be used effectively for image enhancement, In addition to providing useful image statistics.
- Histograms are simple to calculate in software and lend themselves to economic hardware implementations, thus making them a popular tool for real-time image processing.

➢ Histogram Processing Example



➢ Four basic image types: dark, light, low contrast, high contrast, and their corresponding histograms.

Histogram Processing

- In digital image processing, the histogram is used for graphical representation of a digital image.

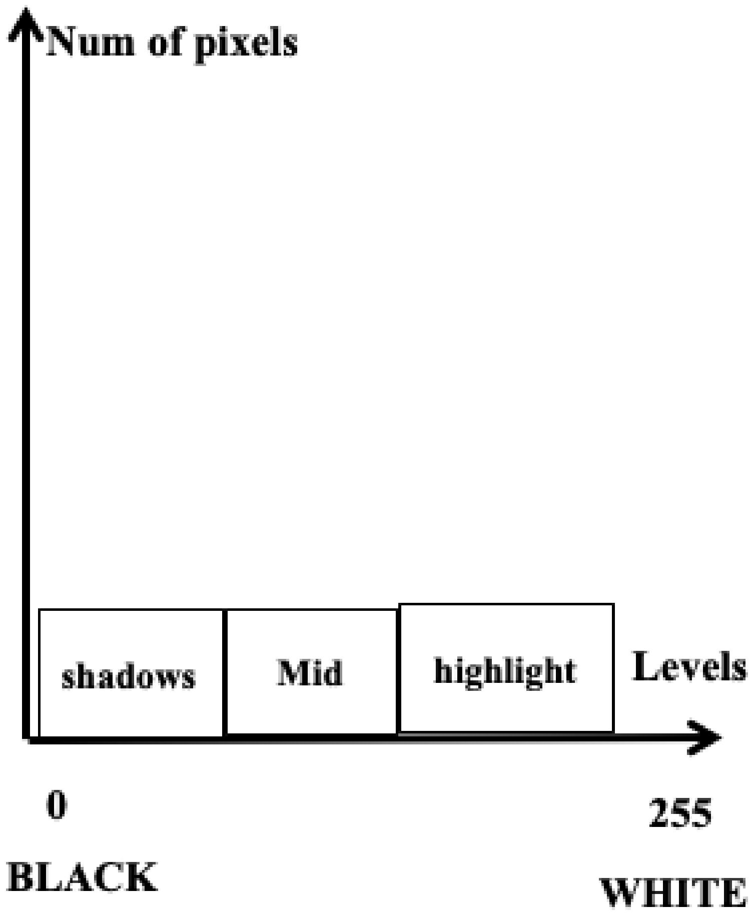
- A graph is a plot by the number of pixels for each tonal value.

- Nowadays, image histogram is present in digital cameras. Photographers use them to see the distribution of tones captured.

➢ Histogram Processing

- ➢ In a graph, the horizontal axis of the graph is used to represent tonal variations whereas the vertical axis is used to represent the number of pixels in that particular pixel.

- ➢ Black and dark areas are represented in the left side of the horizontal axis, medium grey color is represented in the middle, and the vertical axis represents the size of the area.



➢ How It Works:

- The operation is very simple. The image is scanned in a single pass and a running count of the number of pixels found at each intensity value is kept. This is then used to construct a suitable histogram.

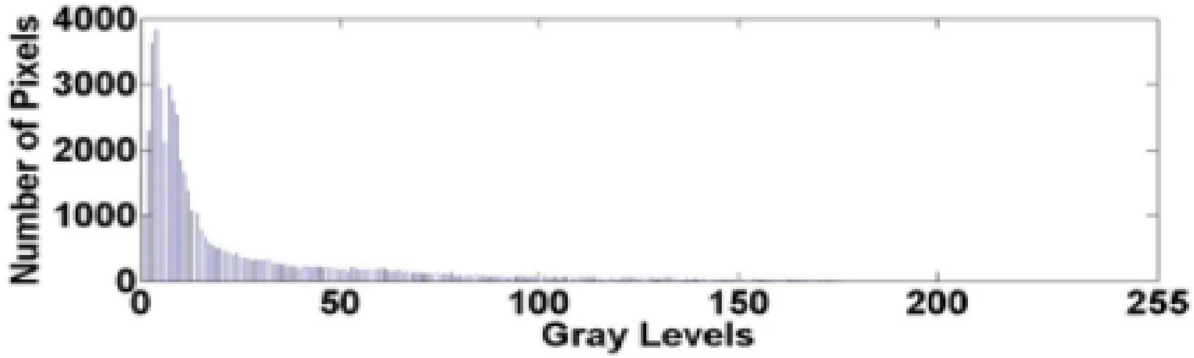
Histogram of the above scenery

- Applications of Histograms:

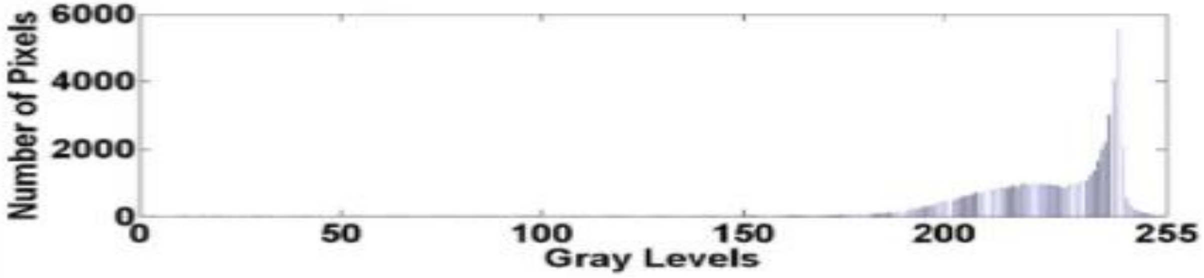
• The brightness of the image can be adjusted by having the details of its histogram.

• If we have input and output histogram of an image, we can determine which type of transformation is applied in the algorithm.

➢ Histogram Processing



(a) (b)



(a) (b)