IMAGE PROCESSING

Chapter 3: Image enhancement

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1. What is image enhancement

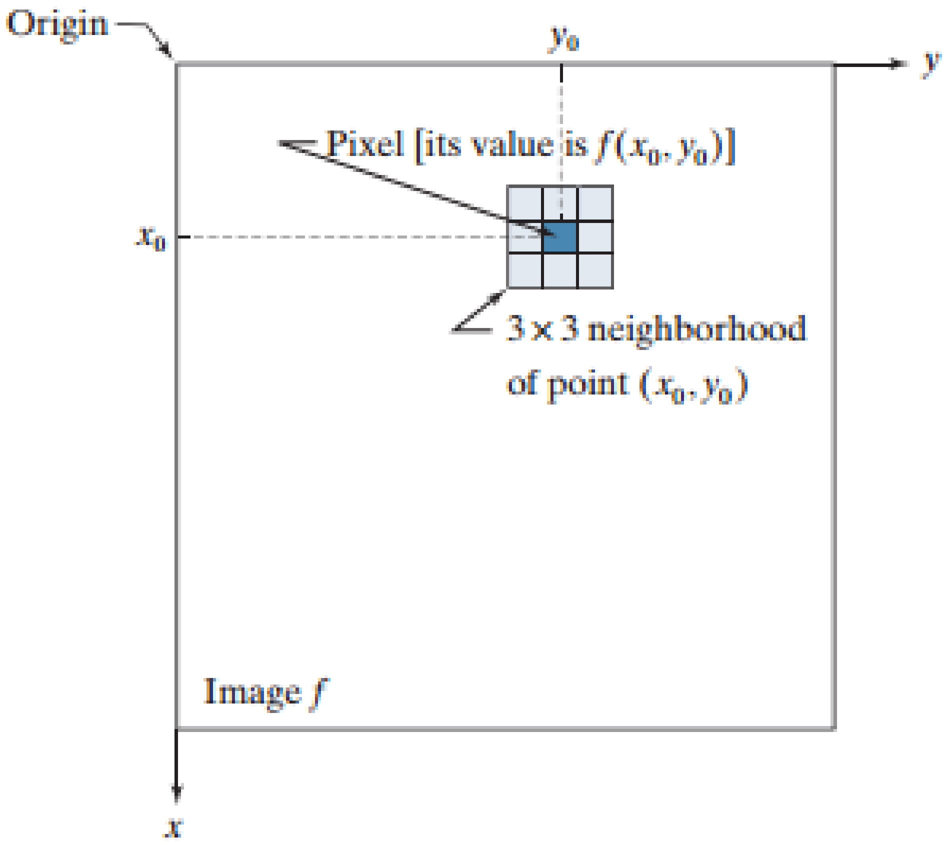
Enhancement is the process of manipulating an image so that the result is more suitable than the original for ***a specific application.*** Thus, for example, a method that is quite useful for enhancing X-ray images may not be the best approach for enhancing infrared images.

The role of enhancement is to adapt the image to better serve its intended use, whether for human interpretation or machine-based analysis:Improving Visual Interpretation, Facilitating Machine Perception, Pre-processing for Analysis, Aesthetic Improvement

Spatial domain, some basic intensity transformation functions

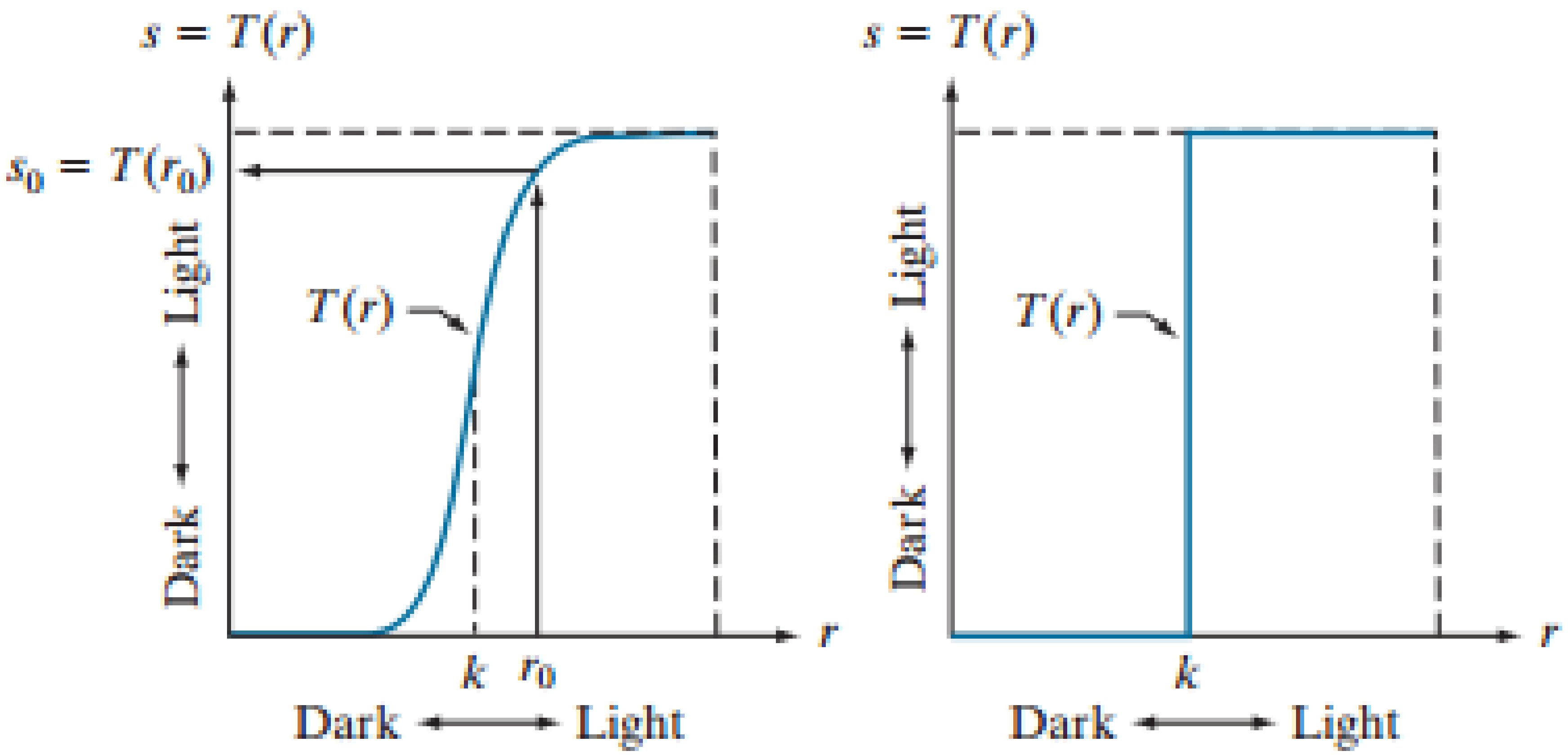
The spatial domain processes we discuss in this chapter are based on

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



f(x,y) is an input image, g(x,y) is the output image, and T is an operator on f defined over a neighborhood of point (x,y)

Some basic intensity transformation functions



The smallest possible neighborhood is of size 1x1. s= T(r)

Some basic intensity transformation functions

Image negatives   S=L-1-r, intensity levels in the range [0,L-1]

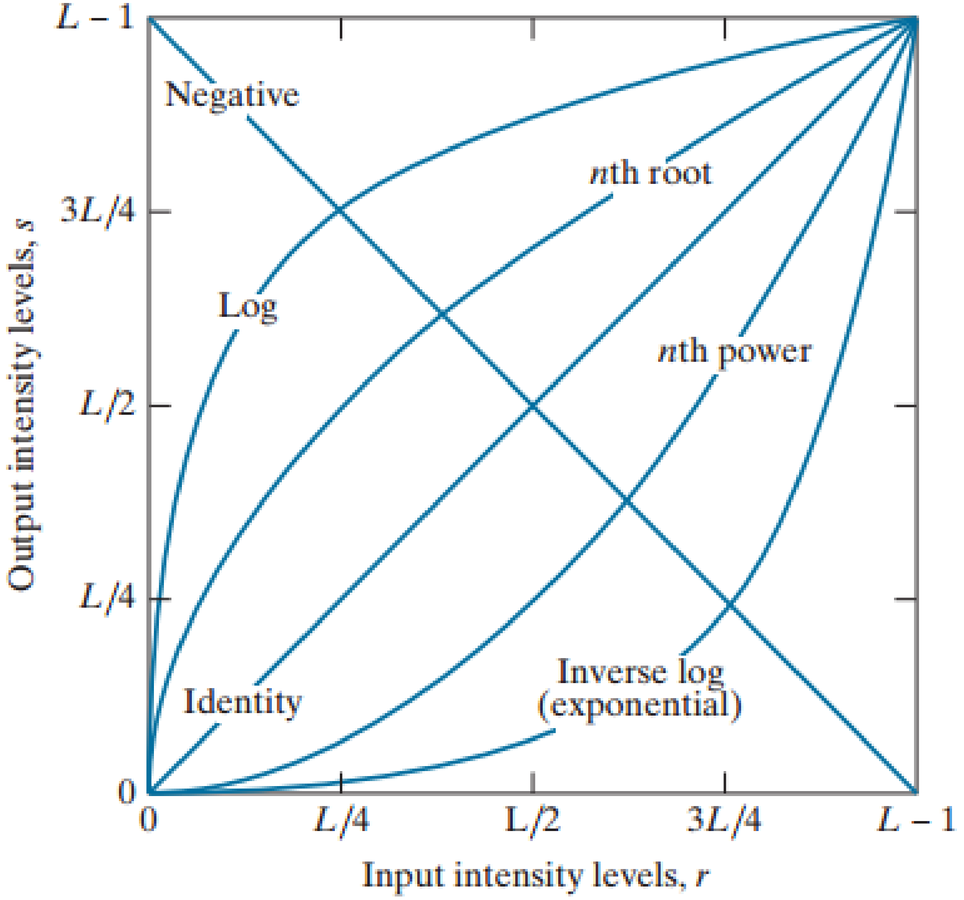
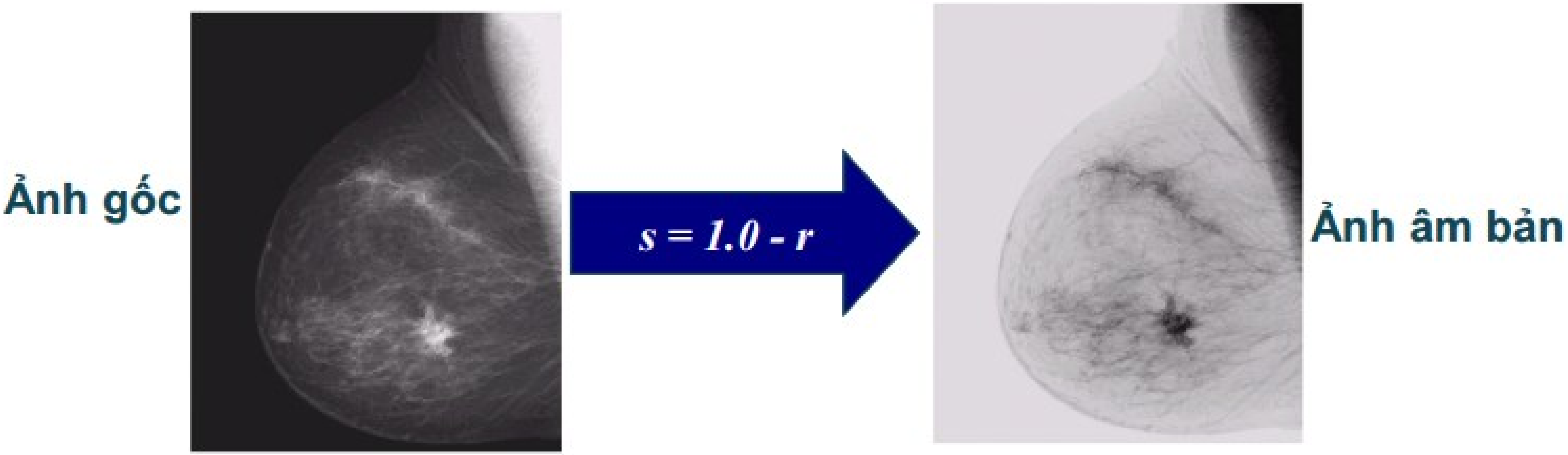
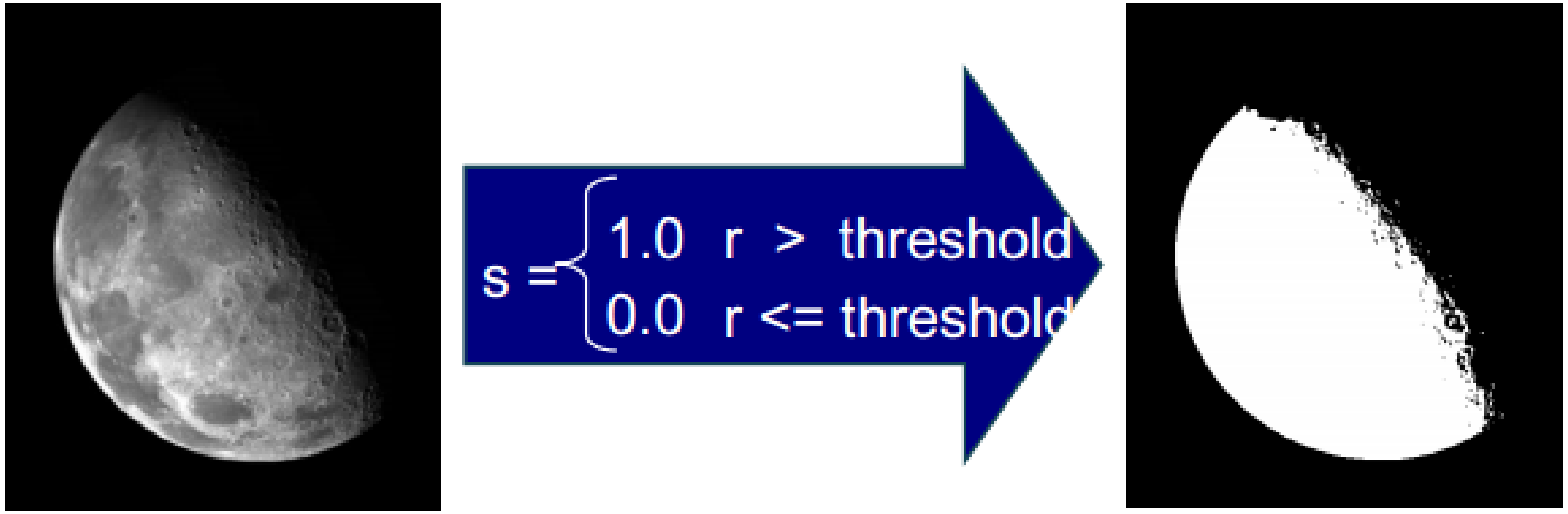


Image negatives



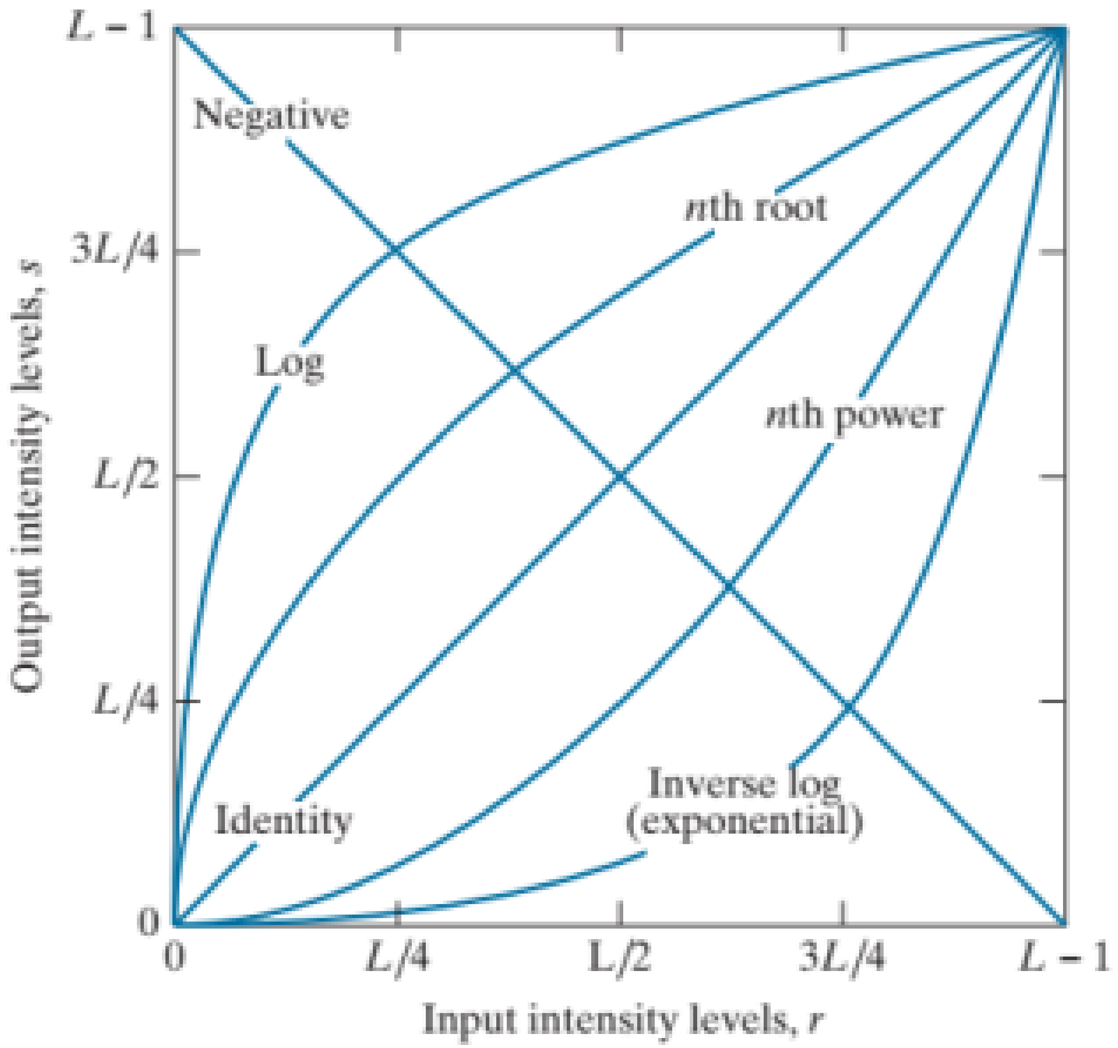
Thresholding transformation

- Is used to highlight the objects of interest against the background of the image



Some grayscale transformation functions

- Biến đổi tuyến tính
  - Negative/Identity
- Biến đổi logarithm
  - Log/Inverse log
- Biến đổi hàm mũ
  - n^{th} power/n^{th} root

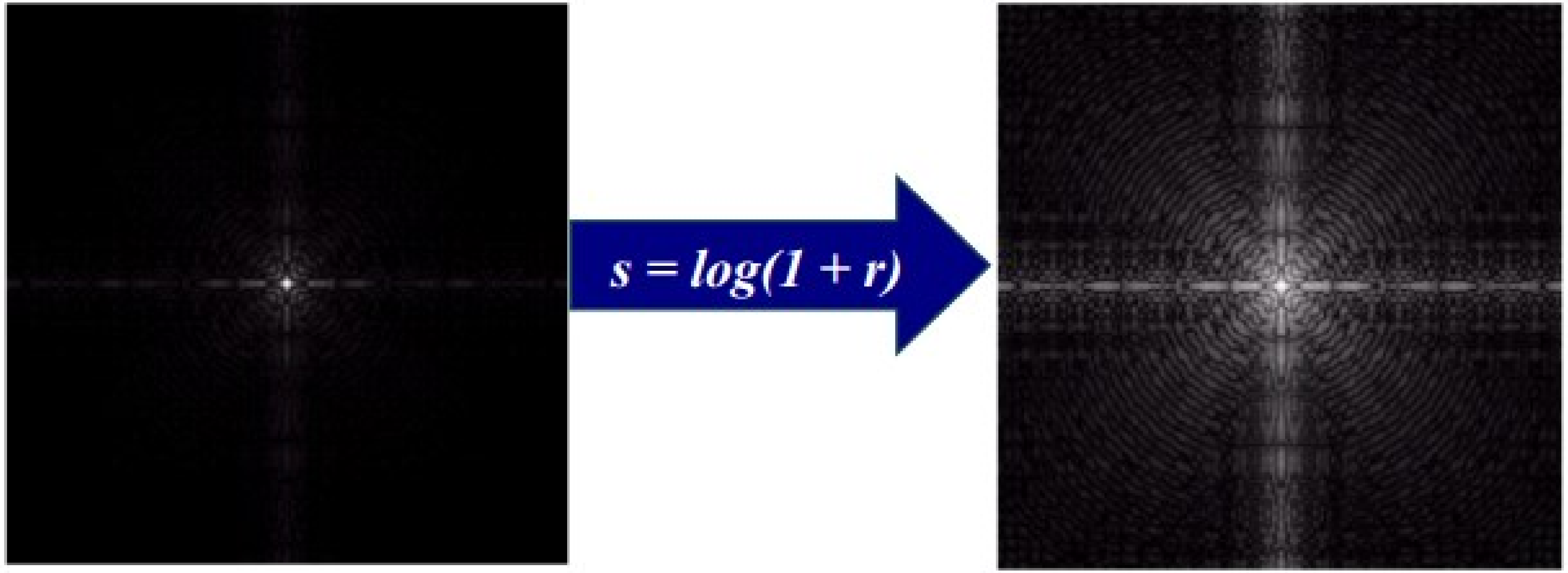


Logarithm transformation

- A technique used to enhance the brightness of dark regions in an image while compressing the bright regions. This helps to highlight details in the dark areas, resulting in an image with higher
- $s = c * \log(1 + r)$; s is the output pixel value, r is the input pixel value, c is a scaling constant.

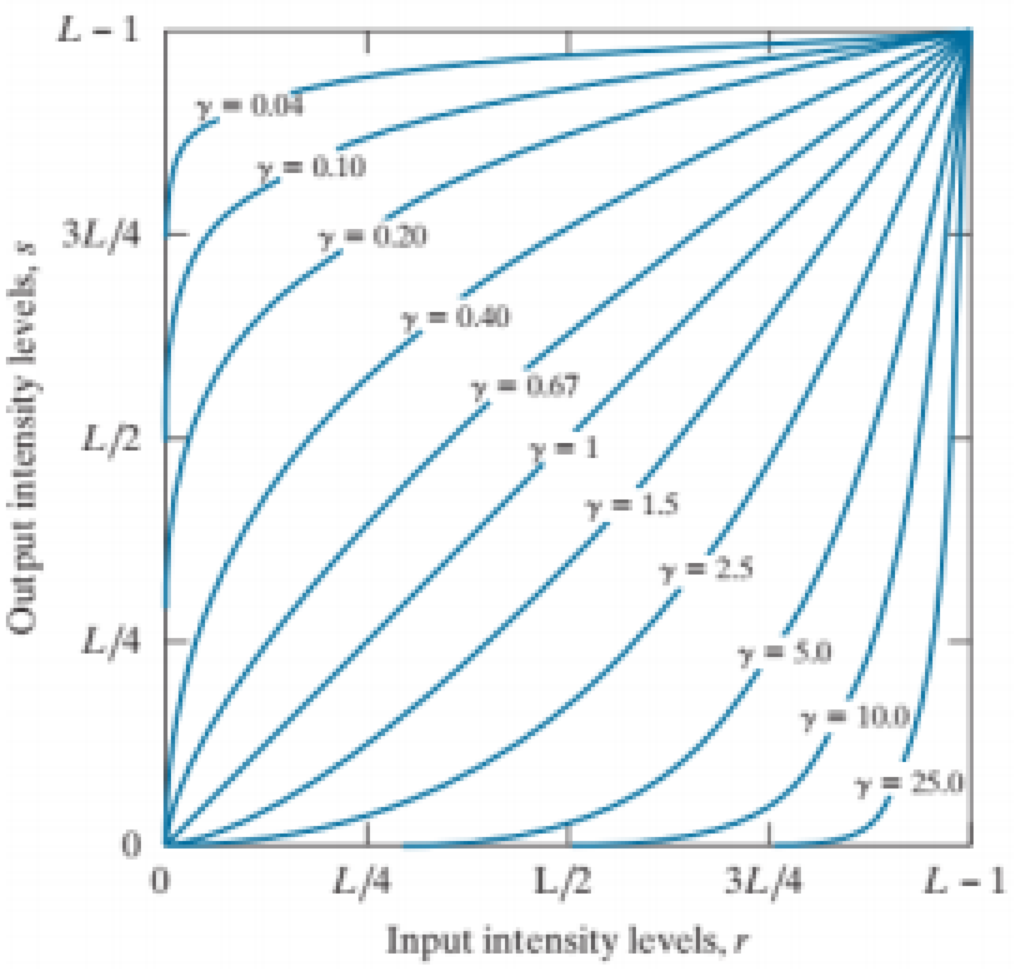
X-ray images, a larger value of c, e.g., c = 2, can be used to enhance the visibility of bone structures.For low-light images, a value of c between 0.5 and 1 is often suitable for noise reduction and detail enhancement in dark regions.

Logarithm transformation

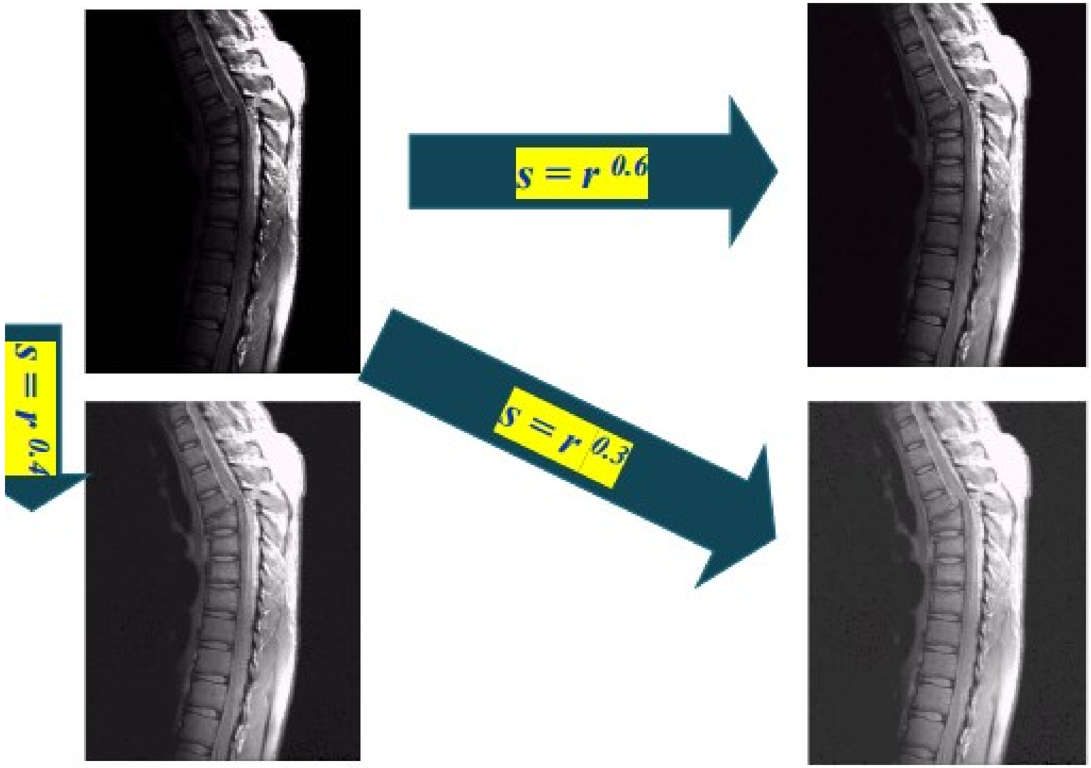


Power-root transformation

- s = c * r^γ;s -the output pixel value, r-the input pixel value, c-a scaling factor, and γ -the gamma value.
- The effect of the transformation depends on the value of γ. For γ < 1, the transformation compresses the higher intensity values and expands the lower ones, enhancing the visibility of details in dark regions. Conversely, for γ > 1, the transformation compresses the lower intensity values and expands the higher ones, reducing the risk of clipping in bright regions.

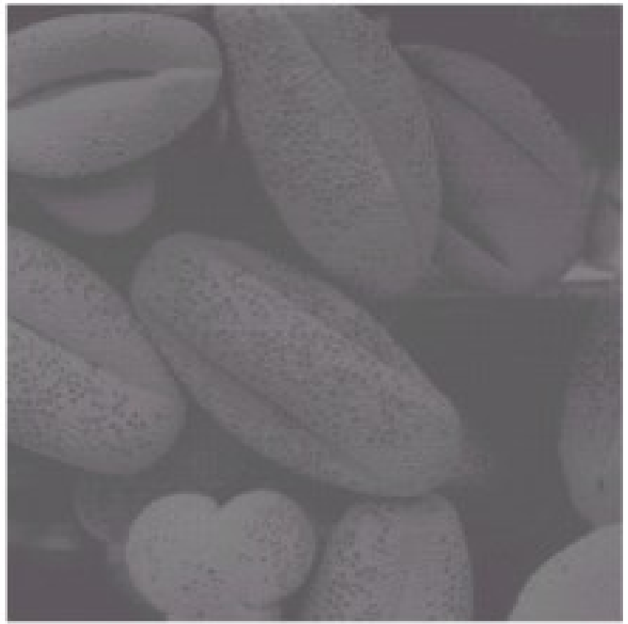


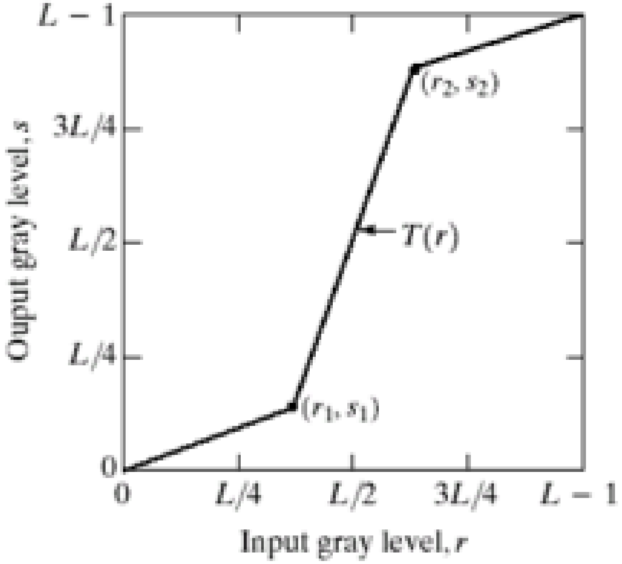
Power-root transformation



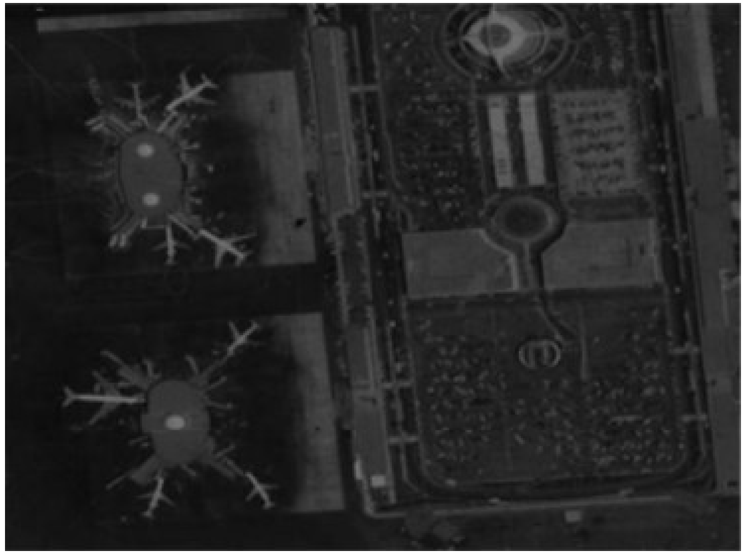
Comments

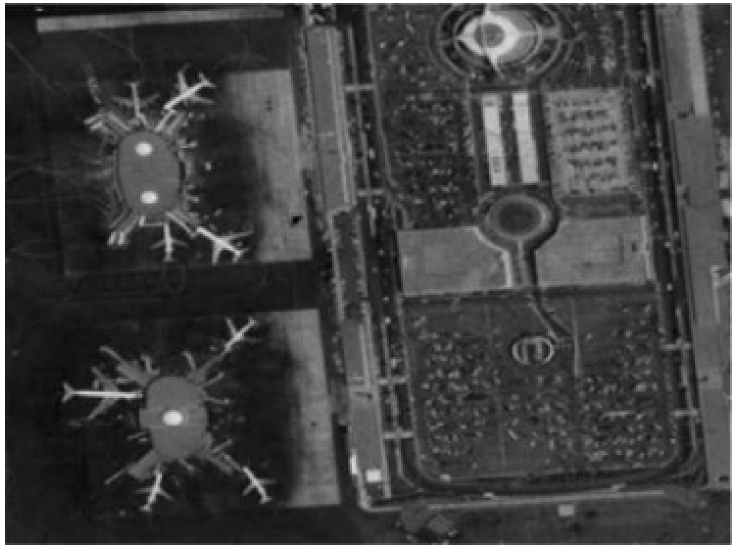
- By segmenting the image and applying different mathematical functions to each segment, we can achieve a more flexible and tailored intensity transformation.





Contrast Stretching Giãn độ tương phản

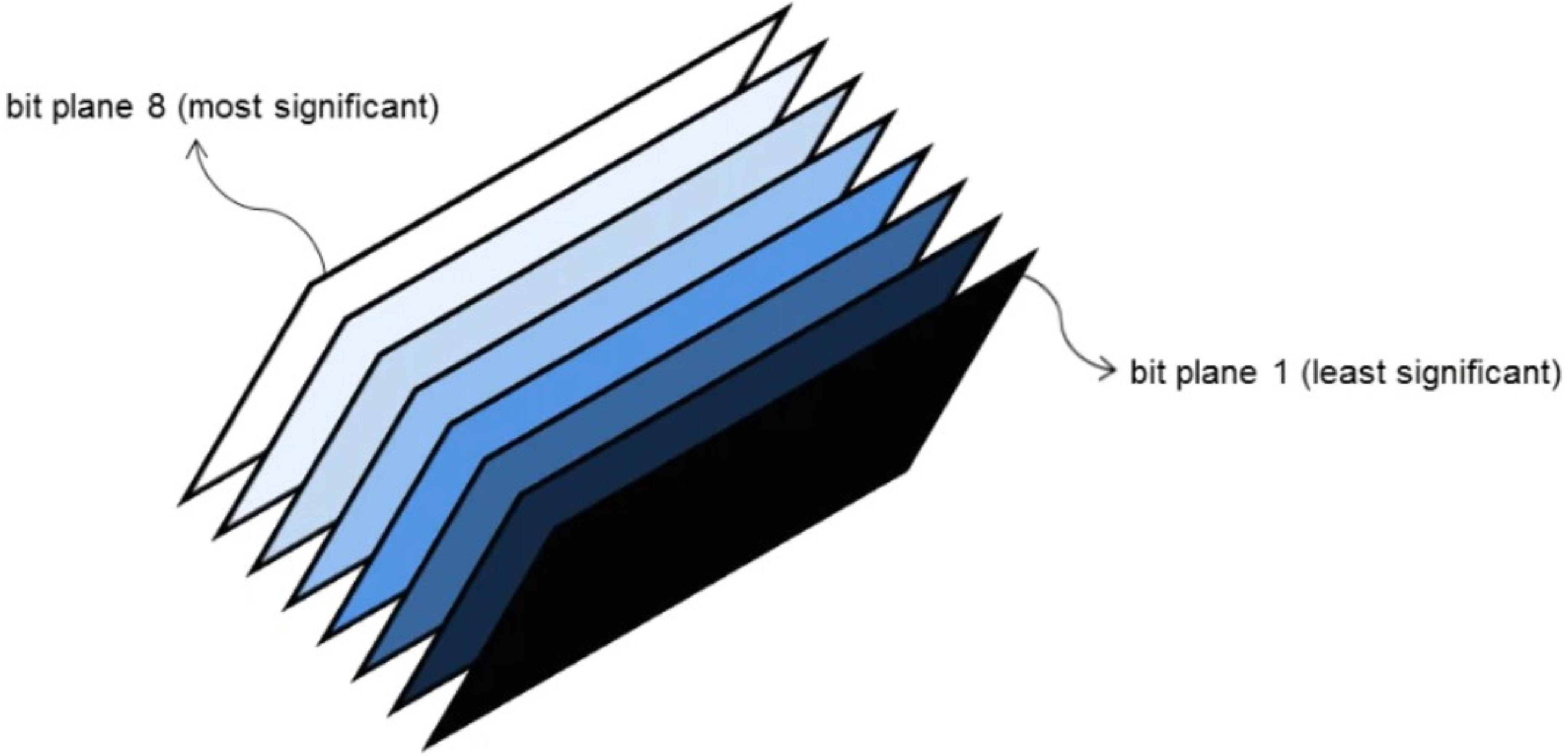




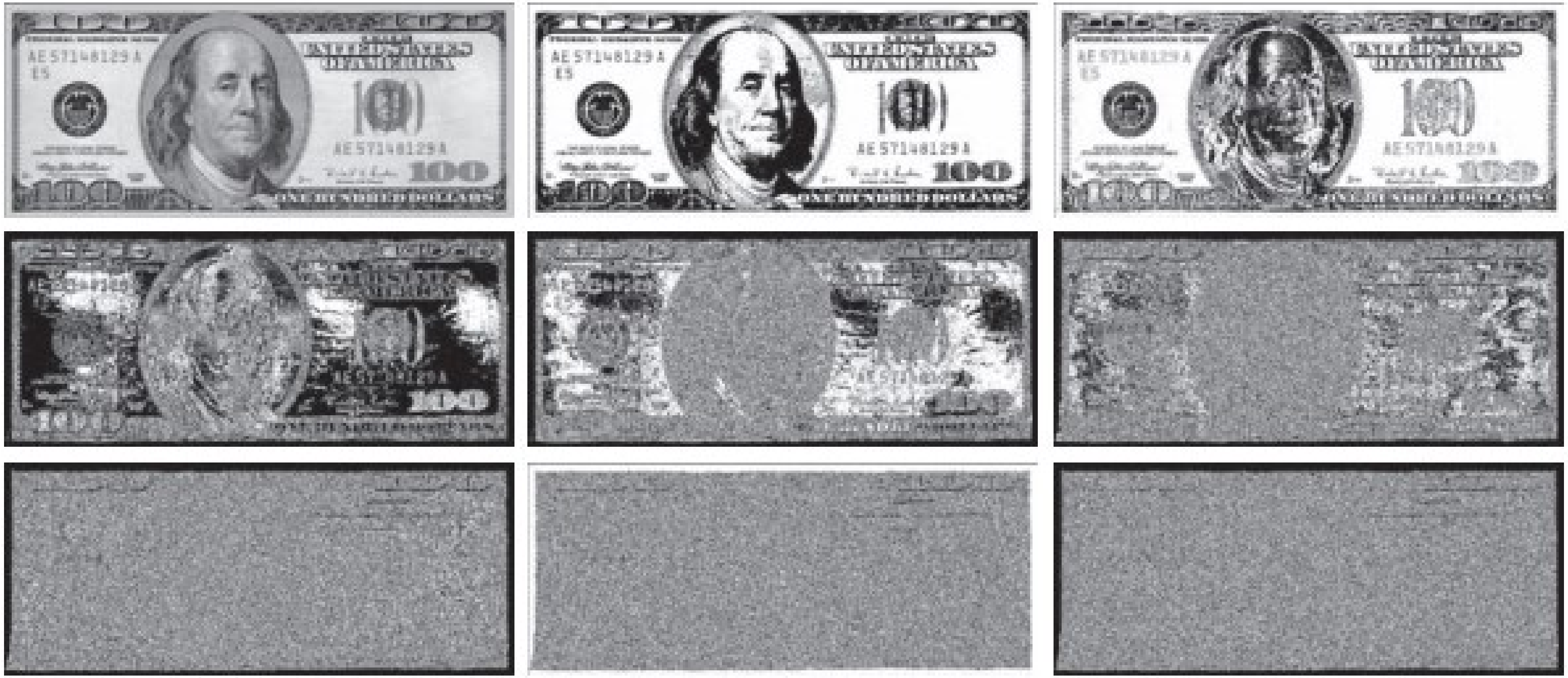
$$y(\mathbf{n}) = \frac{2^B - 1}{x_{max} - x_{min}}(x(\mathbf{n}) - x_{min})$$

$$x_{max} = \max_{\mathbf{n}} x(\mathbf{n}) \qquad x_{min} = \min_{\mathbf{n}} x(\mathbf{n})$$

Bit-Plane slicing- Cắt theo mặt phẳng bít

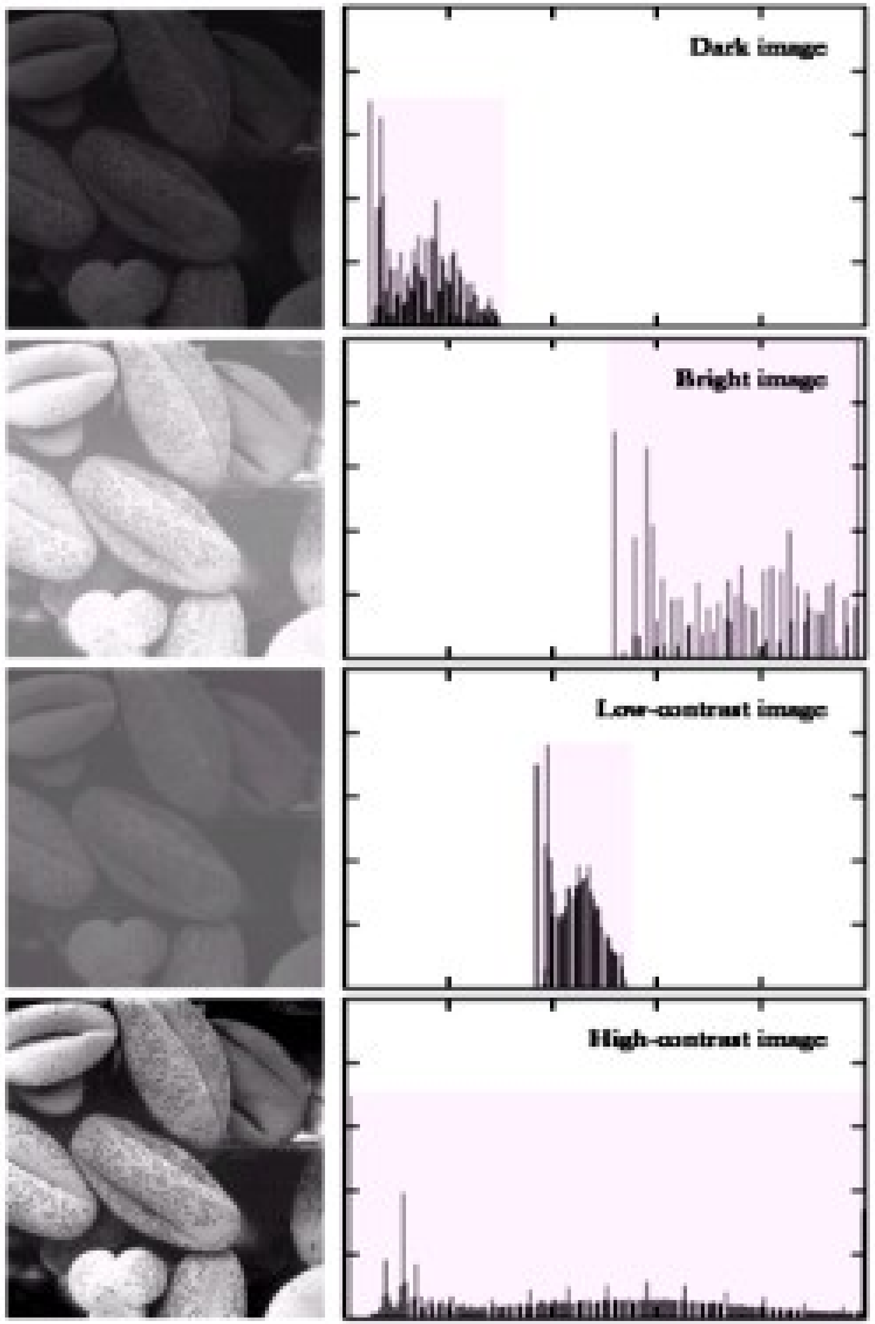


Bit-Plane slicing- Cắt theo mặt phẳng bít



a	b	c
d	e	f
g	h	i

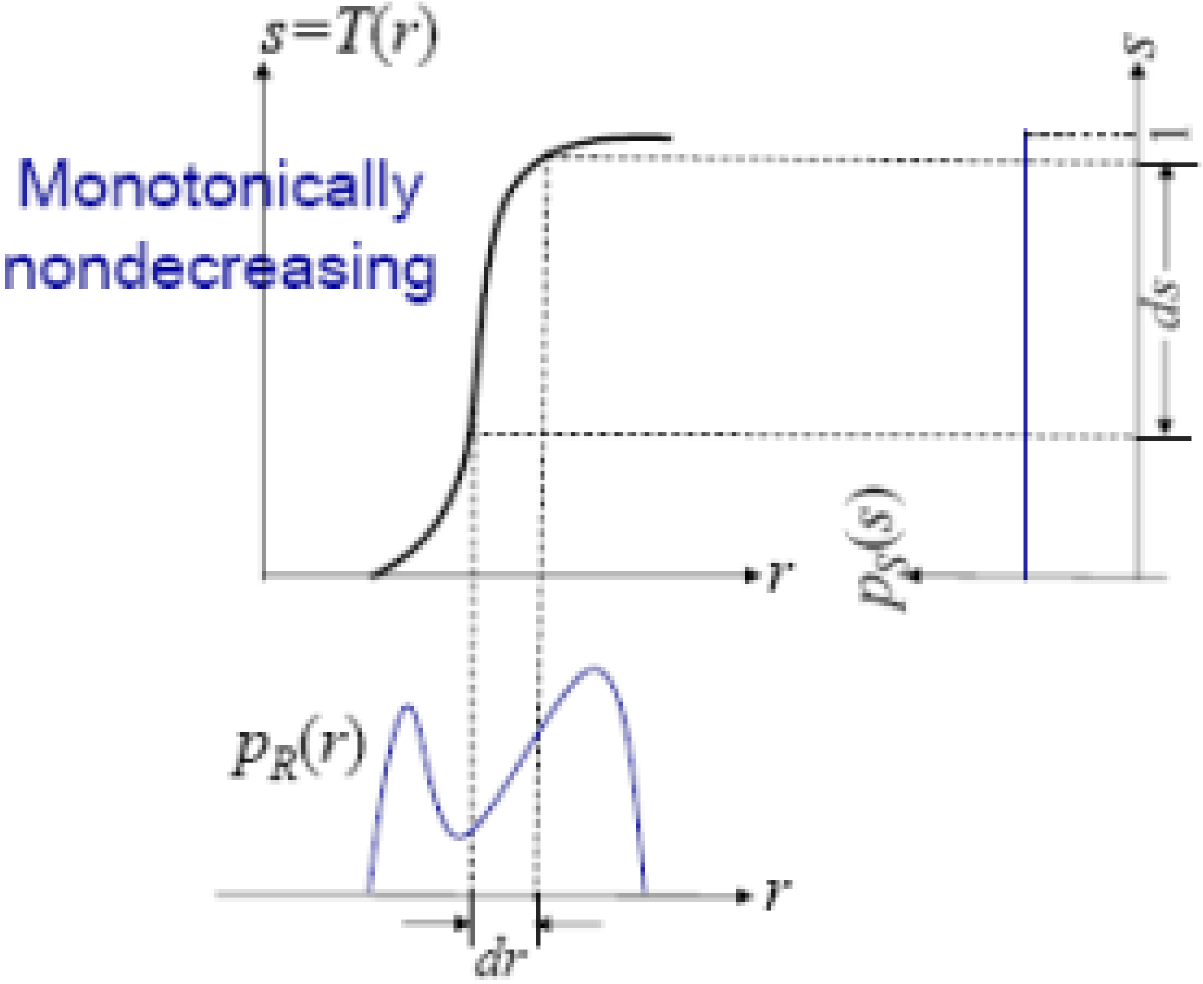
FIGURE 3.14 (a) An 8-bit gray-scale image of size 550 × 1192 pixels. (b) through (i) Bit planes 8 through 1, with bit plane 1 corresponding to the least significant bit. Each bit plane is a binary image..



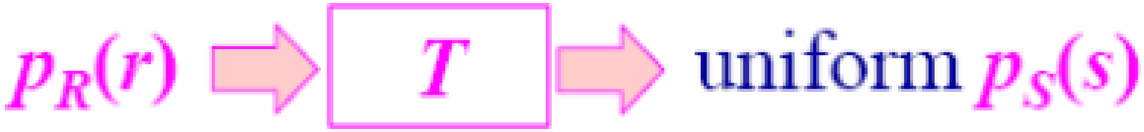
Histogram processing

In a high-contrast image, the grayscale values tend to cluster at the extremes, exhibits a stretched histogram

Histogram Equalization



T ?



Histogram process equalization

- Biểu đồ của ảnh có mức xám trong khoảng [0, L – 1] là hàm rời rạc có dạng như sau:
- $p(r_k) = \frac{n_k}{n}$ với $\begin{cases} n_k & \text{là số lượng pixel có giá trị xám } r_k \\ n & \text{là tổng số pixel của ảnh} \end{cases}$
- Hàm $p(r_k)$ mô tả tỷ lệ giữa tổng số pixel có mức xám r_k và tổng số pixel của ảnh
- Histogram mô tả tổng thể phân bố mức xám của ảnh

Algorithm histogram equalization

r_k: mức xám đầu vào

s_k : mức xám đầu ra

k: dải cường độ sáng

n_j : tần suất của cường độ j

n: tổng số điểm ảnh

L’: số mức xám ở ảnh đầu ra (thông thường bằng số mức xám đầu vào)

$$
\begin{aligned}
s_k &= T(r_k) \\
&= (L'-1)\sum_{j=0}^{k} p_r(r_j) \\
&= (L'-1)\sum_{j=0}^{k} \frac{n_j}{n}
\end{aligned}
$$

Example

Gray Levels (r_k)	No. of pixels (n_k)	$p(r_k) = n_k/n$ (PDF)	S_k (CDF)	$S_k \times 7$	Histogram Equalization level
0	9	0.141	0.141	0.987	1
1	8	0.125	0.266	1.862	2
2	11	0.172	0.438	3.066	3
3	4	0.0625	0.5005	3.5035	4
4	10	0.156	0.6565	4.5955	5
5	15	0.234	0.8905	6.2335	6
6	4	0.0625	0.953	6.671	7
7	3	0.047	1	7	7

$n = 64$

Gray levels	1	2	3	4	5	6	7
No. of pixels	9	8	11	4	10	15	7

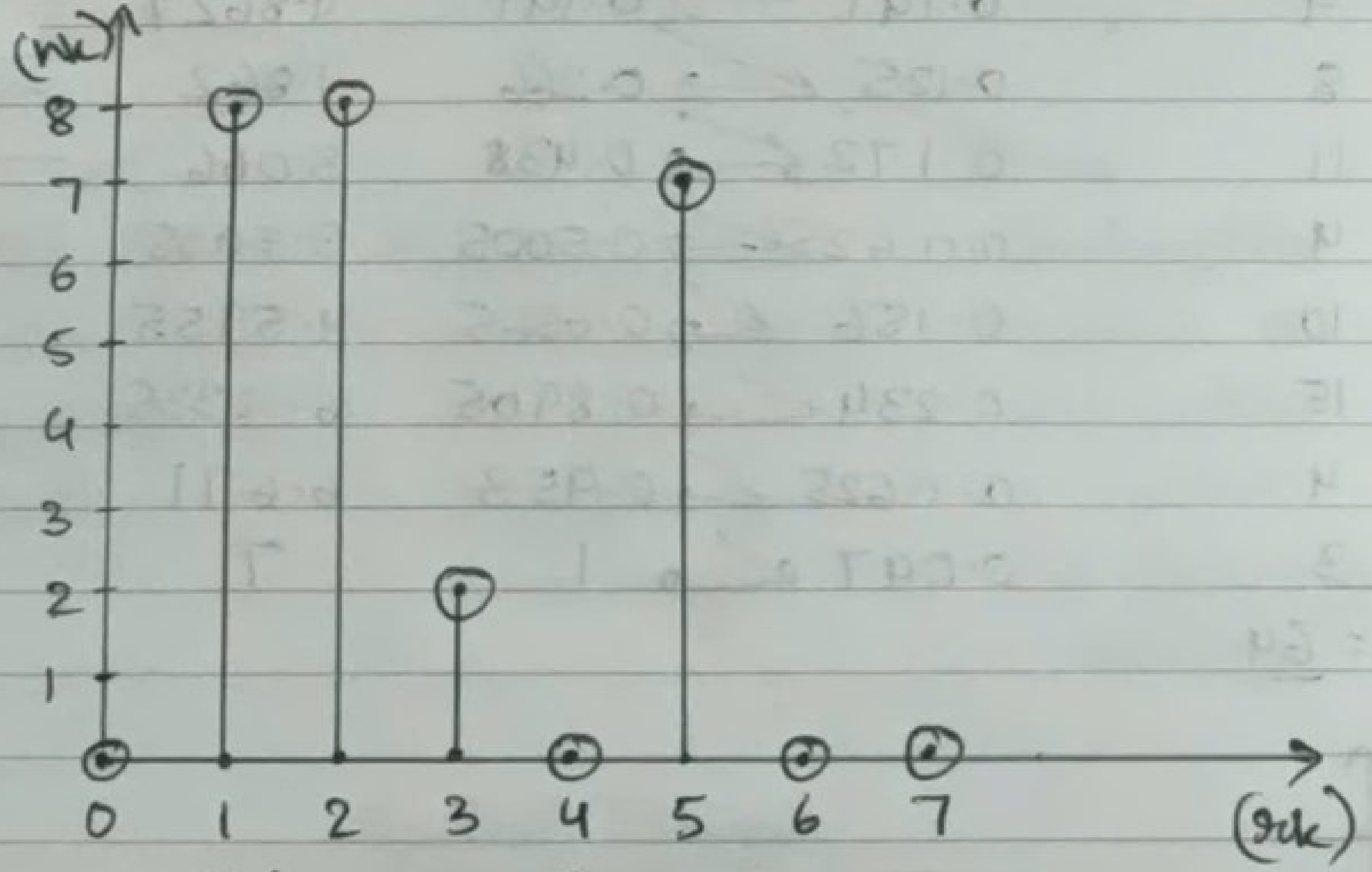
Example

1	2	1	1	1
2	5	3	5	2
2	5	5	5	2
2	5	3	5	2
1	1	1	2	1

Input image

Example

Gray levels (r_k)	0	1	2	3	4	5	6	7
No. of pixels (n_k)	0	8	8	2	0	7	0	0



Histogram of input image

Example

Gray Levels (r_k)	No. of pixels (n_k)	$p(r_k) = n_k/n$ (PDF)	S_k (CDF)	$S_k \times 7$	Histogram Equalization level
0	0	0	0	0	0
1	8	0.32	0.32	2.24	2
2	8	0.32	0.64	4.48	4
3	2	0.08	0.72	5.04	5
4	0	0	0.72	5.04	5
5	7	0.28	1	7	7
6	0	0	1	7	7
7	0	0	1	7	7

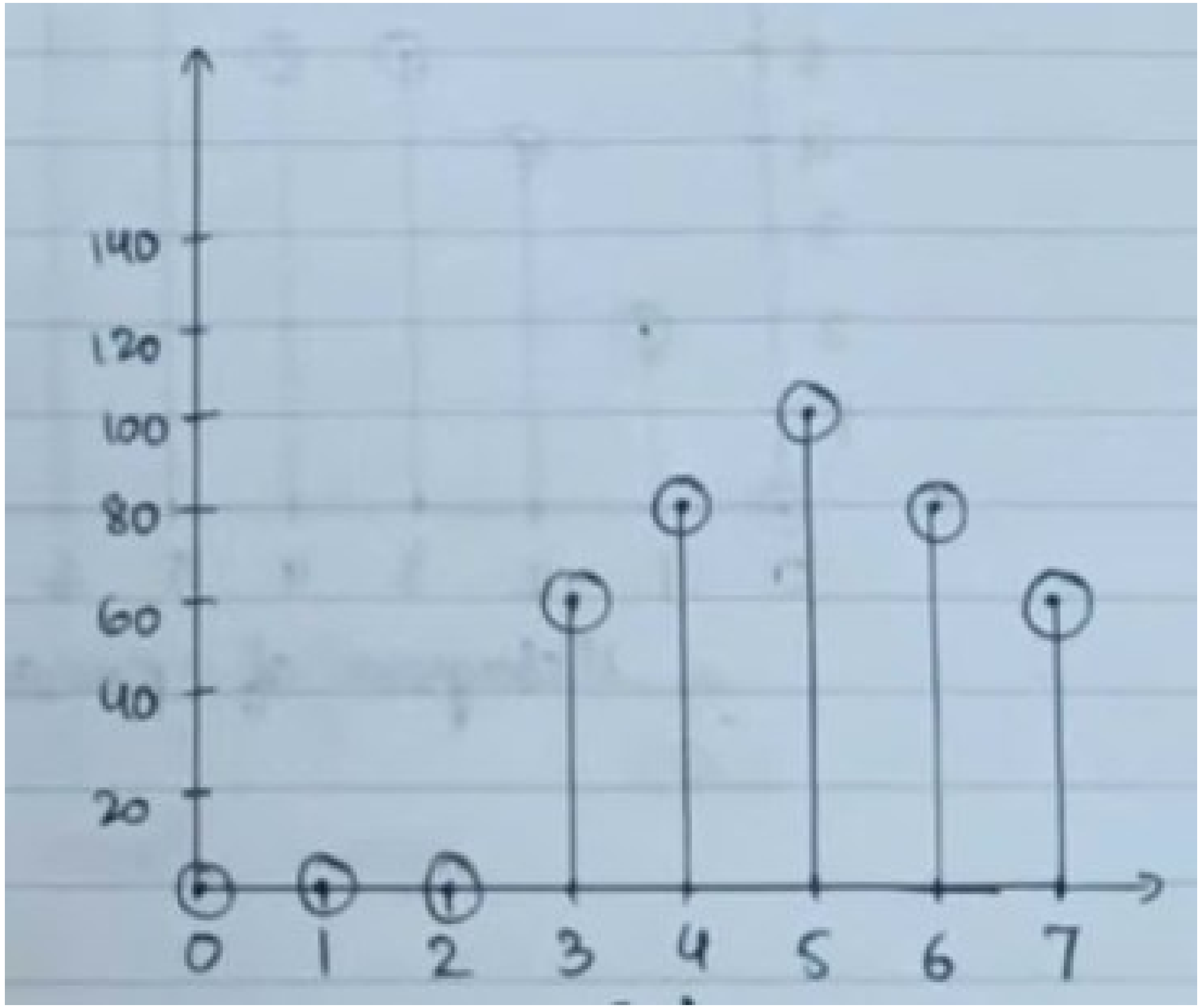
Example

1	2	1	1	1
2	5	3	5	2
2	5	5	5	2
2	5	3	5	2
1	1	1	2	1

Input image

Output image?

Example



Histogram of Output image

Example

Gray level	n_k
0	80
1	100
2	90
3	60
4	30
5	20
6	10
7	0

Gray level	n_k	$p(r_k) = n_k/n$ (PDF)	S_k (CDF)	$S_k \times 7$	Histogram equalization	New
0	80	0.20	0.20	1.4	1	80
1	100	0.25	0.45	3.15	3	100
2	90	0.23	0.68	4.76	5	90
3	60	0.15	0.83	5.81	6	60+30 90
4	30	0.07	0.9	6.3	6	
5	20	0.05	0.95	6.65	7	20+10 30
6	10	0.02	0.97	6.79	7	
7	0	0	0.97	6.79	7	
	$n = 390$					

- Given the image I, draw the grayscale histogram and perform histogram equalization. Find the image I' after the histogram equalization.

$$I = \begin{pmatrix} 1 & 2 & 0 & 4 \\ 1 & 0 & 0 & 7 \\ 2 & 2 & 1 & 0 \\ 4 & 1 & 2 & 1 \\ 2 & 0 & 1 & 1 \end{pmatrix}$$