4105 Computer Vision

Lecture 3

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Image Enhancement

Image Enhancement

- **Enhancement objectives**
  - *Better Appearance*
  - *Noise Removal*
  - *Facilitates Further Processing Steps (segmentation,…..)*
- **Enhancement classifications**

  Domain

  Spatial

  Frequency

  application

  Point based

  Region based

  Global based

Image Enhancement

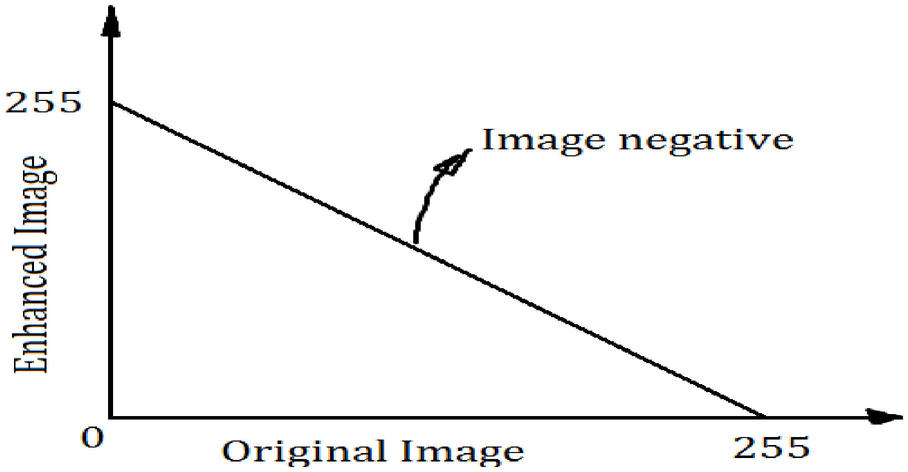
Enhancement Concept

Mapping h: $f \quad (x, y) \quad (orignal\ image\ matrix)\ to\ \ f'(x, y)\ (enhanced\ image\ matrix)$

- $f'(x, y)\ (enhanced\ image\ matrix)$
    - **Less in noise**
    - **Better in appearance**
    - **Suite more segmentation, detection, recognition**

1. Image Negative

- $0^{black} \Rightarrow \quad 255^{white}$
  $255^{white} \Rightarrow \quad 0^{black}$



$$f'(x,y)_{negative\ Image} = (L-1) - f(x,y)_{original\ image}$$

L=2^q

Image negative

Negative simple program:-

For $i = 0 : N - 1$

For $j = 0 : M - 1$

$$fe(i, j) = (L - 1) - f(i, j)$$

$End; \ //j$

$End; //i$

- $//fe : \ is\ the\ negative$; f: $is\ the\ original\ matrix$

Contrast Stretching and Contraction

- Contrast? difference between objects constituting the images.

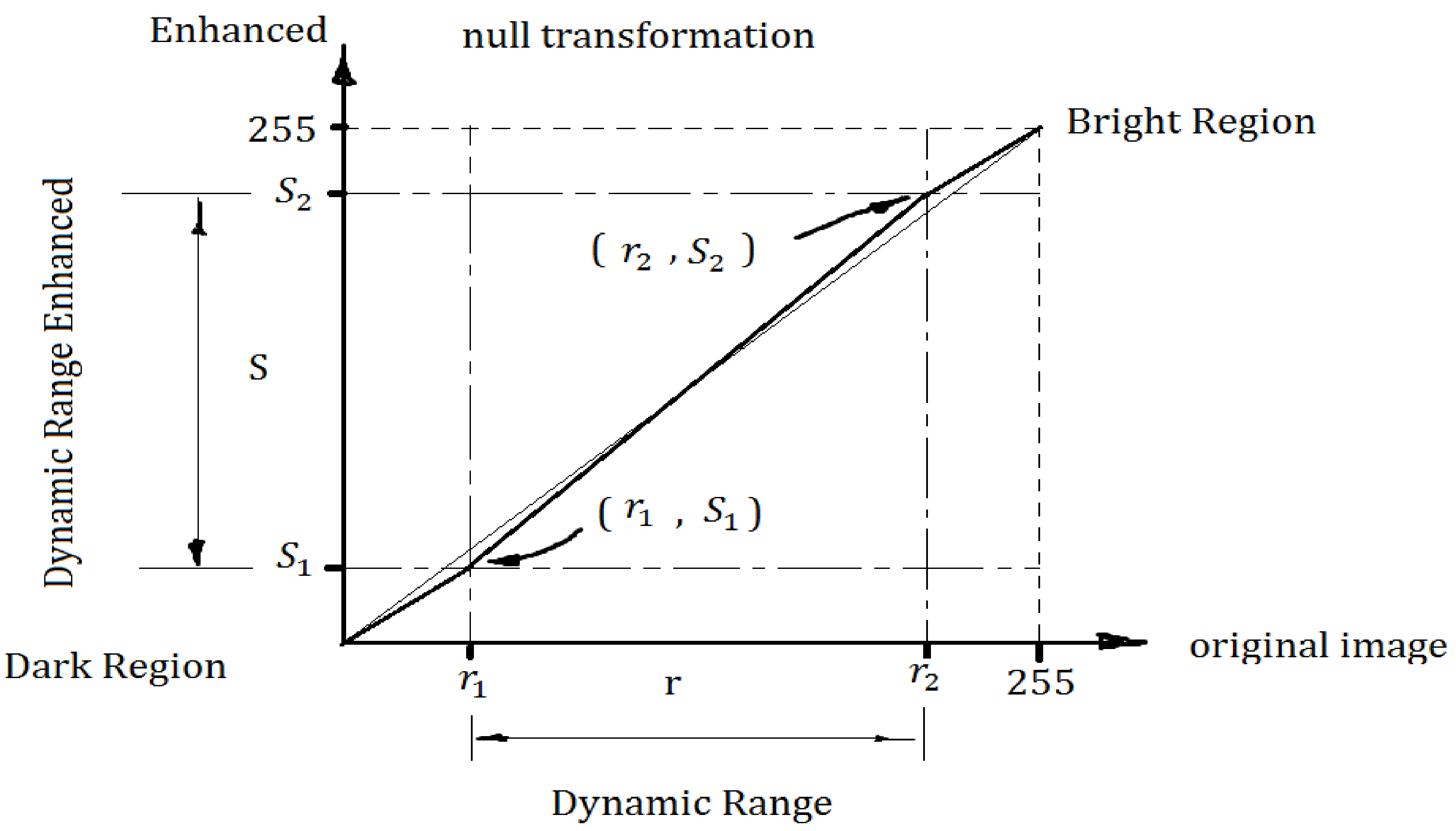
Low contrast

High contrast

Contrast Stretching and Contraction

- Generally low contrast images occupies limited range of available range
- Look at available range for gray images as:-
  - Too dark
  - Dynamic range
  - Too white
- First and last range will not hurt to compress
- The middle contains image information if we stretch it will increase difference between constituting elements → increase contrast

Contrast Stretching and Contraction



Contrast Stretching and Contraction

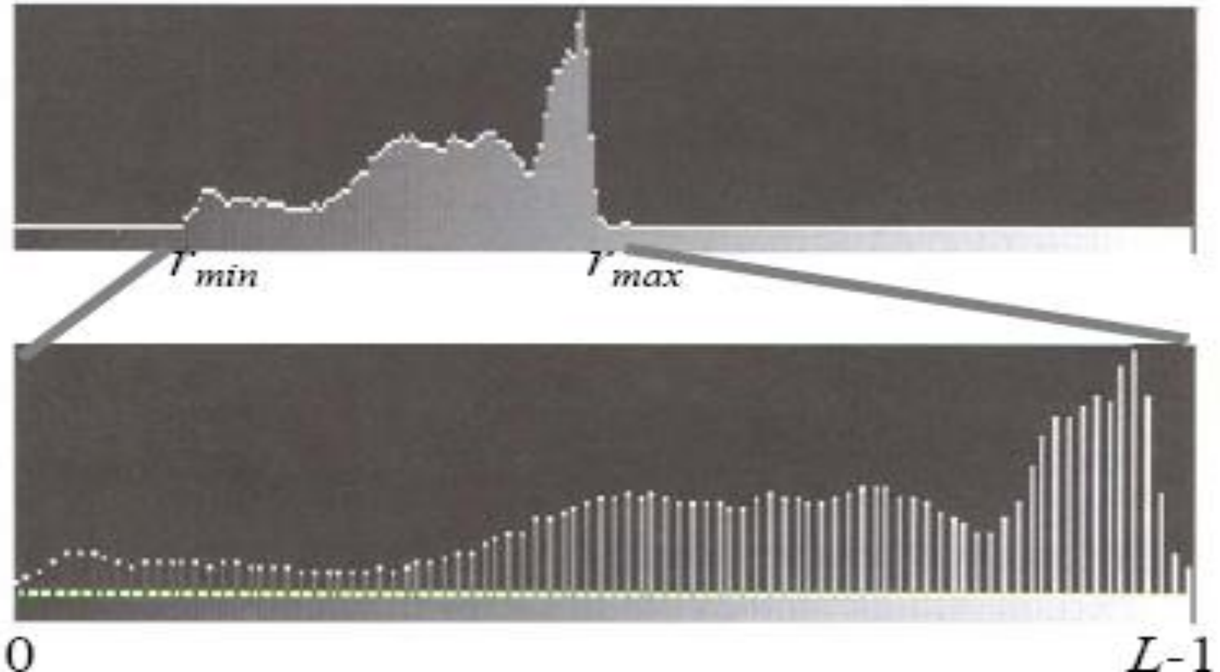
- $first\ line: 0 \rightarrow r_1$
  - $f'(x,y) = f \quad (x,y)\frac{s_1}{r_1}$
- $second\ line: \ r_1 \rightarrow r_2$
  - $f'(x,y) = f(x,y)\frac{s_2-s_1}{r_2-r_1} + \ s_1 - \ r_1\frac{s_2-s_1}{r_2-r_1}$
- $third\ line: \ r_2 \rightarrow 255$
  - $f'(x,y) = f(x,y)\frac{(L-1)-s_2}{(L-1)-r_2} + (L-1) - (L-1)\frac{L-s_2}{L-r_2}$
- Contrast contraction is needed when same object occupies wide range of grays that makes you see as more than one object
- Contraction is the same process but values of $s_1 > \ r_1 \ and s_2 < \ r_2$

Contrast stretching through histogram

If r_{max} and r_{min} are the maximum and minimum gray level of the input image and L is the total gray levels of output image

The transformation function for contrast stretching will be

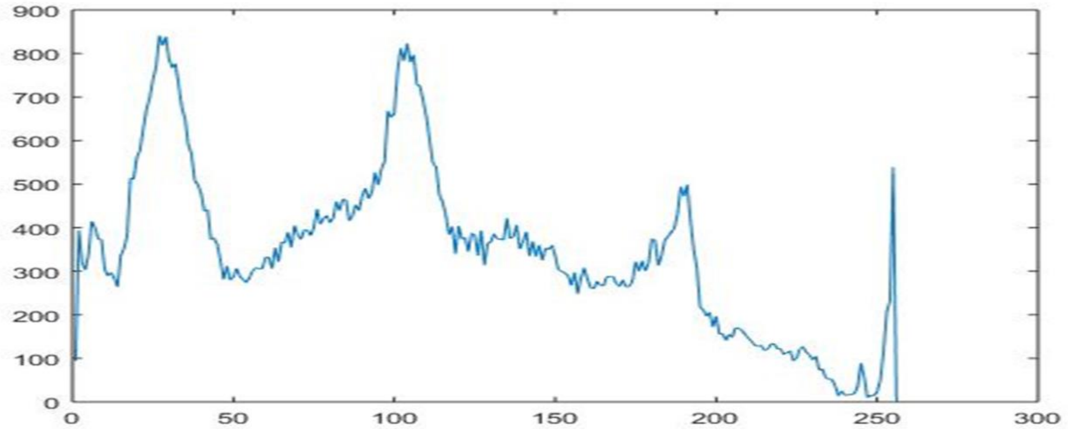
$$s = T(r) = (r - r_{\min})\left(\frac{L}{r_{\max} - r_{\min}}\right)$$



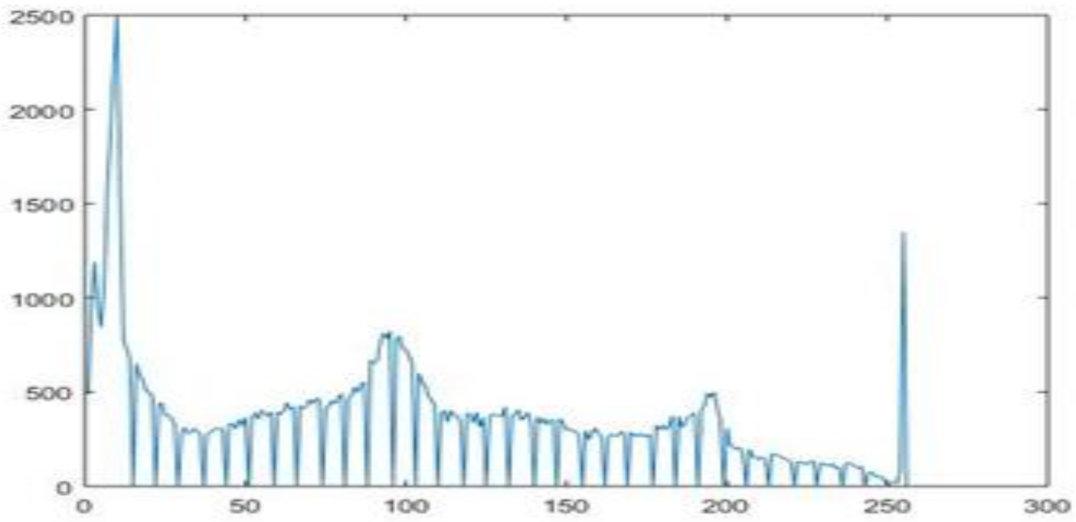
Contrast Stretching

Contrast Stretching 30 ---→10 240-------→250

After and before contrast stretching

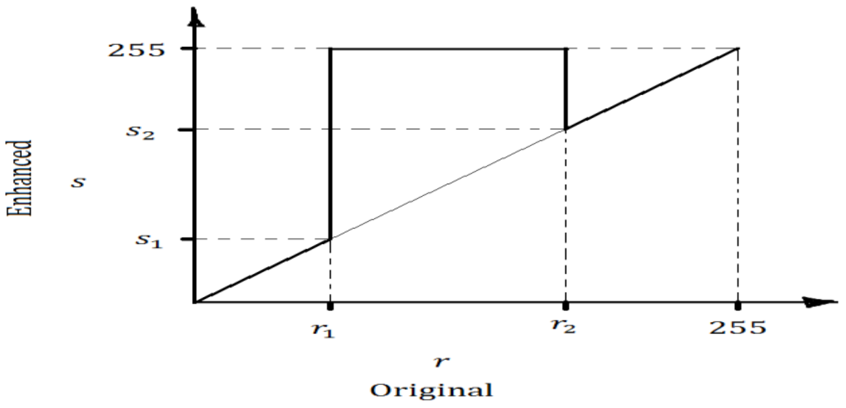


Histogram after stretch



Gray level slicing

- To High light range of interest colors/gray values



$$if(f(i,j) < r_2 \ \&\& \ f(i,j) > r_1)$$
$$fp(i,j) = 255 = L - 1;$$
Else
$$fp(i,j) = f(i,j);$$

r1=100,r2=115

Bit Plane Slicing

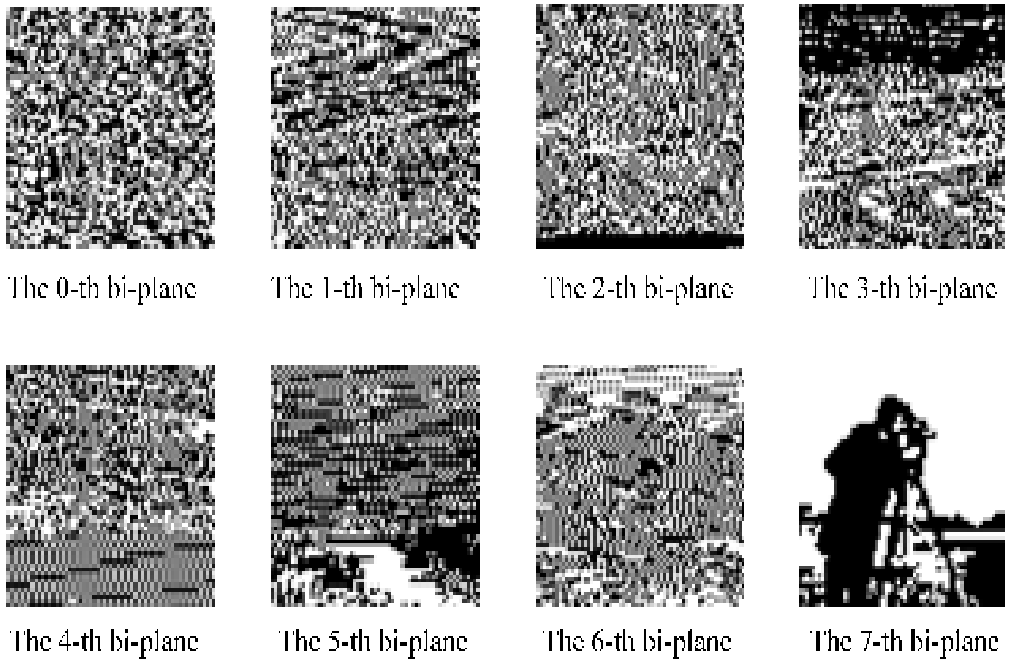
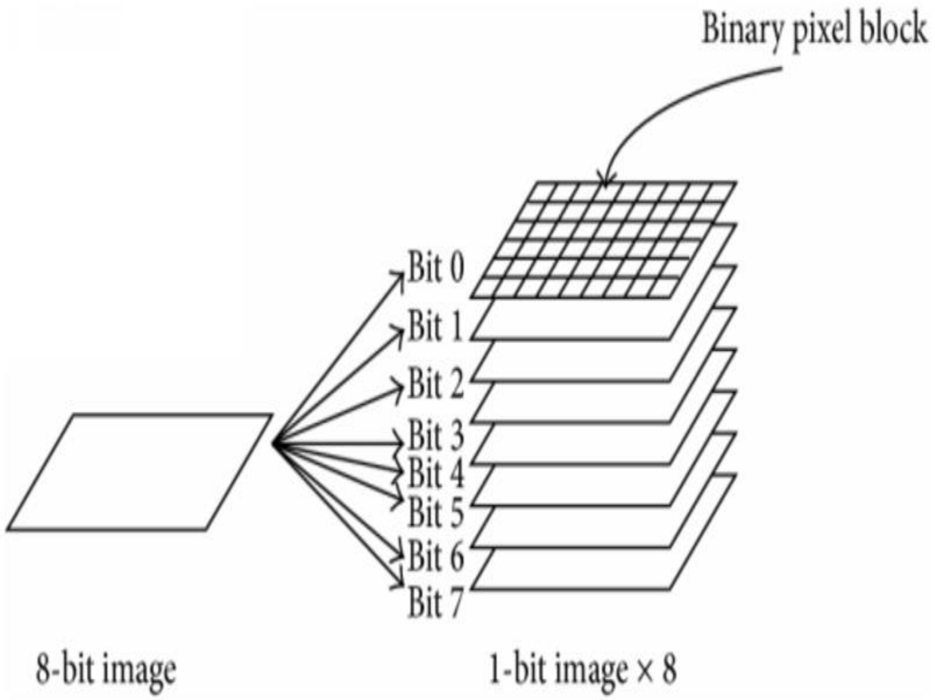


FIGURE 13. Bitplanes of the image in Fig. 12 (c).



Bit Plane Slicing

Setting plane 7 to 1

Setting plane 7 to 0

Bit Plane Slicing

Setting plane 7 to 1

Setting plane 7 to 0

bitplanes 0,1,2 set 1, 0

Histogram Equalization

- The idea is to spread out the histogram so that it makes full use of the dynamic range of the image.

- For example, if an image is very dark, most of the intensities might lie in the range 0-50. By choosing f to spread out the intensity values, we can make fuller use of the available intensities, and make darker parts of an image easier to understand.

- If we choose f to make the histogram of the new image, J, as uniform as possible, we call this **histogram equalization.**

Histogram Processing

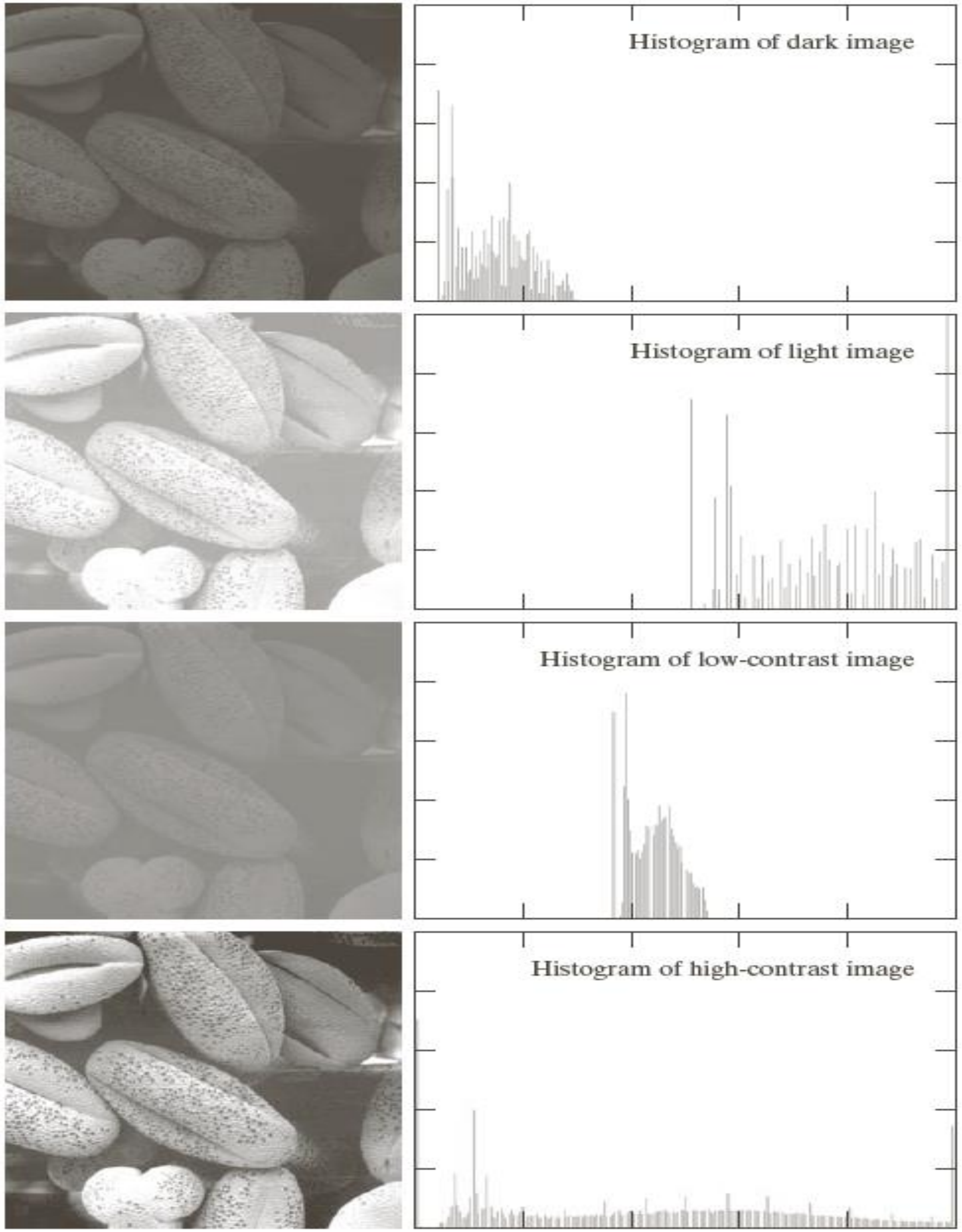
Histogram $\quad h(r_k) = n_k$

r_k is the k^{th} intensity value

n_k is the number of pixels in the image with intensity r_k

Normalized histogram $\quad p(r_k) = \dfrac{n_k}{MN}$

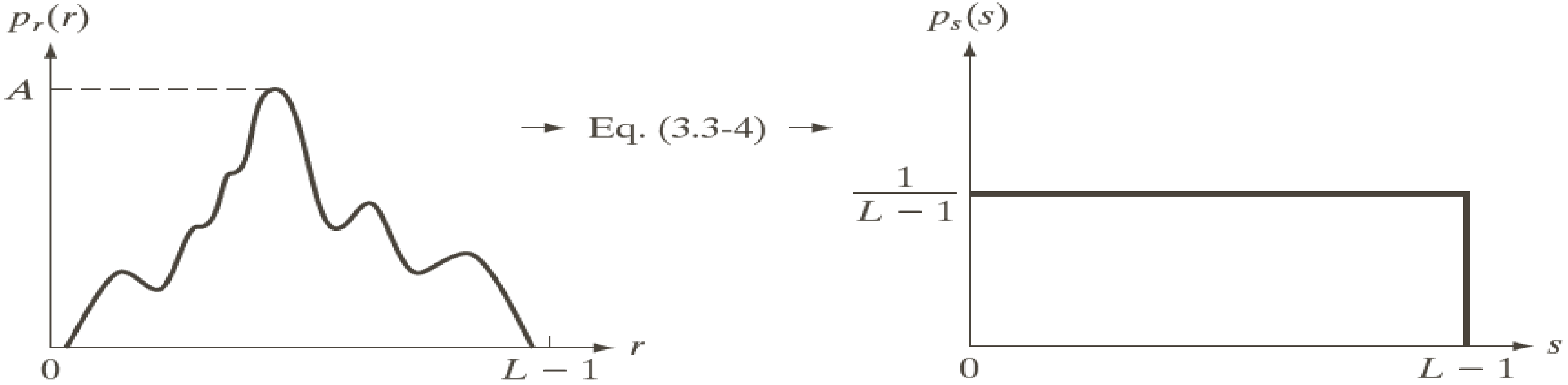
n_k: the number of pixels in the image of size $\mathrm{M} \times \mathrm{N}$ with intensity r_k


Histogram of dark image
Histogram of light image
Histogram of low-contrast image
Histogram of high-contrast image

Histogram Equalization

The intensity levels in an image may be viewed as random variables in the interval [0, L-1].

Let $p_r(r)$ and $p_s(s)$ denote the probability density function (PDF) of random variables r and s.



a b

FIGURE 3.18 (a) An arbitrary PDF. (b) Result of applying the transformation in Eq. (3.3-4) to all intensity levels, r. The resulting intensities, s, have a uniform PDF, independently of the form of the PDF of the r's.

Histogram Equalization

Discrete values:

$$s_k = T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j)$$

$$= (L-1)\sum_{j=0}^{k} \frac{n_j}{MN} = \frac{L-1}{MN}\sum_{j=0}^{k} n_j \qquad \text{k=0,1,..., L-1}$$

Example: Histogram Equalization

Suppose that a 3-bit image (L=8) of size 64 × 64 pixels (MN = 4096) has the intensity distribution shown in following table.

r_k	n_k	$p_r(r_k) = n_k/MN$
$r_0 = 0$	790	0.19
$r_1 = 1$	1023	0.25
$r_2 = 2$	850	0.21
$r_3 = 3$	656	0.16
$r_4 = 4$	329	0.08
$r_5 = 5$	245	0.06
$r_6 = 6$	122	0.03
$r_7 = 7$	81	0.02

Get the histogram equalization transformation function and give the $p_s(s_k)$ for each s_k.

Example: Histogram Equalization

r_k	n_k	$p_r(r_k) = n_k/MN$
$r_0 = 0$	790	0.19
$r_1 = 1$	1023	0.25
$r_2 = 2$	850	0.21
$r_3 = 3$	656	0.16
$r_4 = 4$	329	0.08
$r_5 = 5$	245	0.06
$r_6 = 6$	122	0.03
$r_7 = 7$	81	0.02

$$s_0 = T(r_0) = 7\sum_{j=0}^{0} p_r(r_j) = 7 \times 0.19 = 1.33 \quad \rightarrow 1$$

$$s_1 = T(r_1) = 7\sum_{j=0}^{1} p_r(r_j) = 7 \times (0.19 + 0.25) = 3.08 \quad \rightarrow 3$$

$$s_2 = 4.55 \quad \rightarrow 5 \qquad s_3 = 5.67 \quad \rightarrow 6$$

$$s_4 = 6.23 \quad \rightarrow 6 \qquad s_5 = 6.65 \quad \rightarrow 7$$

$$s_6 = 6.86 \quad \rightarrow 7 \qquad s_7 = 7.00 \quad \rightarrow 7$$

How to do it

- **Get Cumulative Distribution Function (CDF).**
- **Either multiply by the either full range or target range**
- **Then add range start**
- **That makes a gray or color coincide with place in allocated range in terms of it cumulative value**
- **Gray of cumulative 0.5 will be in the middle of the range, of 0.7 will be in 0.7 of the range, so on**

Two Examples

Gray value	Count	Probability	Cumulative	Cumulative * L-1	New Gray	Range	Cumulative * Range +Start	New Gray
20	100	0.02	0.02	5.1	5	210	24.2	24
70	500	0.1	0.12	30.6	31		45.2	45
90	1000	0.2	0.32	81.6	82		87.2	87
120	2000	0.4	0.72	183.6	184		171.2	171
150	700	0.14	0.86	219.3	219		200.6	201
170	300	0.06	0.92	234.6	235		213.2	213
200	300	0.06	0.98	249.9	250		225.8	226
230	100	0.02	1	255	255		230	230
	5000	1						

How to get Enhanced Image

Conversion Table Full Range

20	5
70	31
90	82
120	184
150	219
170	235
200	250
230	255

Conversion Table In Range

20	24
70	45
90	87
120	171
150	201
170	213
200	226
230	230

Histogram Equalization