江西理工大學 信息工程学院
JIANGXI UNIVERSITY OF SCIENCE AND TECHNOLOGY SCHOOL OF INFORMATION ENGINEERING

Digital Image Processing

数字图像处理

Lecture 07:

Image enhancement

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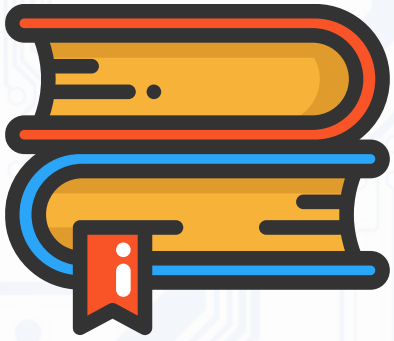

Digital Image Processing

LECTURE 07: **Image enhancement**

图像增强 Túxiàng zēngqiáng

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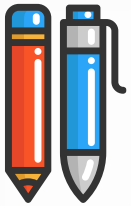


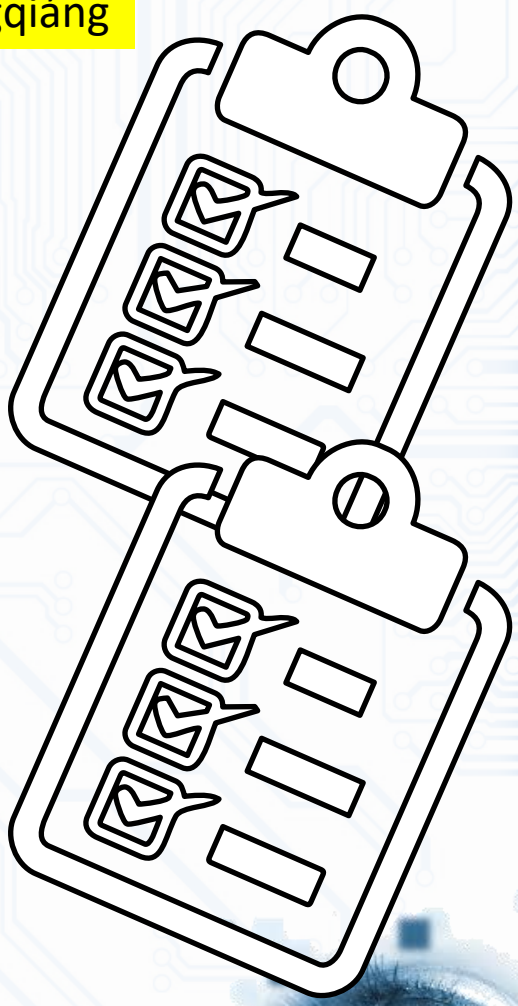
Agenda

图像增强 Túxiàng zēngqiáng

- **Image enhancement**

1. Gray Level Transformation

灰度变换 Huī dù biànhuàn



Enhancement

增强 Zēngqiáng

- 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.**
- 增强的主要目的是对图像进行处理，使其结果比原始图像更适合于特定的应用。

具体应用。 Jùtǐ yìngyòng.

- The word *specific* is important, because it establishes at the outset that the techniques discussed in this chapter are very much problem oriented. “具体”这个词很重要，因为它从一开始就表明本章讨论的技术是非常面向问题的。
- Thus, for example, a method that is quite useful for enhancing X-ray images may not necessarily be the best approach for enhancing pictures of Mars transmitted by a space probe.因此，例如，一种对增强x射线图像非常有用的方法，不一定是增强由太空探测器传输的火星图像的最佳方法。

火星传送 Huǒxīng chuánsòng

X射线 X shèxiàn

Image-processing methods

TYPICAL PROCESSING TECHNIQUES

典型的加工技术
Diǎnxíng de jiāgōng jìshù

- **Image Restoration**
  图像修复
  Túxiàng xiūfù
- **Information Extraction**
  信息抽取
  Xìnxī chōuqǔ
- **Image Enhancement**
  图像增强
  Túxiàng zēngqiáng

图像处理方法 Túxiàng chǔlǐ fāngfǎ

Image-processing methods

图像处理方法可分为三个功能类别：下面将对这些技术和典型处理技术进行定义。

Image-processing methods may be grouped into three functional categories: these are defined below together with lists of typical processing techniques.

- **Image Restoration compensates for data errors, noise and geometric distortions introduced during the scanning, recording, and playback operations.** 图像恢复:补偿在扫描、记录和回放操作期间引入的数据错误、噪声和几何失真。

图像修复 Túxiàng xiūfù

- **Image Enhancement alters the visual impact that the image has on the interpreter in a fashion that improves the information content.**

图像增强 Túxiàng zēngqiáng 图像增强以改进信息内容的方式改变图像对解释器的视觉影响。

- **Information Extraction utilizes the decision-making capability of the computer to recognize and classify pixels on the basis of their digital signatures,** 信息提取利用计算机的决策能力，根据像素的数字签名对其进行识别和分类

信息抽取 Xìnxī chōuqǔ

Image-processing methods

TYPICAL PROCESSING TECHNIQUES

图像修复 Túxiàng xiūfù

Image Restoration

a. Restoring periodic line dropouts
b. Restoring periodic line striping
c. Filtering of random noise
d. Correcting for atmospheric scattering
e. correcting geometric distortions

a .恢复周期线丢失;
b.恢复周期线条纹;
C.过滤随机噪声;
d. 修正大气散射;
e. 校正几何扭曲;

信息抽取 Xìnxī chōuqǔ

Information Extraction

a. Contrast enhancement
b. Intensity, hue, and saturation transformations
c. Density slicing
d. Edge enhancement
e. Making digital mosaics
f. Producing synthetic stereo images

a.对比度增强;
b.强度、色调和饱和度转换;
C. 密度切片
D. 边缘增强;
e. 制作数字马赛克;
F. 制作合成立体图像;

图像增强 Túxiàng zēngqiáng

Image Enhancement

a.Producing principal-component images
b.. Producing ratio images
c. Multispectral classification
d. Producing change-detection image

a.生成主成分图像;
b.制作比例图像;
C. 多光谱分类;
d. 生成变化检测图像

Principle Objective of Enhancement

增强的原则目标 Zēngqiáng de yuánzé mùbiāo

对图像进行处理，使其结果比原始图像更适合于特定的应用。

- Process an image so that the result will be more suitable than the original image for a specific application.
- The suitableness is up to each application.

这个适应性合适取决于每个应用程序。

- A method which is quite useful for enhancing an image may not necessarily be the best approach for enhancing another image.

对增强图像非常有用的方法不一定是增强另一个图像的最佳方法 Duì zēngqiáng túxiàng fēicháng yǒuyòng de fāngfǎ bù yīdìng shì zēngqiáng lìng yīgè túxiàng de zuì jiā fāngfǎ

Enhancement Techniques

Image enhancement:

1. Improving the interpretability or perception of information in images for human viewers提高人类观众对图像信息的可解释性或感知能力
2. Providing `better' input for other automated image processing techniques 为其他自动图像处理技术提供“更好的”输入

Enhancement Techniques

对像素进行空间操作
Duì xiàngsù jìnxíng kōngjiān cāozuò

频域操作图像的傅里叶变换
Pín yù cāozuòtúxiàng de fù lǐ yè biànhuàn

Spatial Operates on pixels

Techniques are based on direct manipulation of pixels in an image
operate directly on pixels
基于对图像中像素的直接操作，直接对像素进行操作

Frequency Domain Operates on **Fourier Transform** of Image

Techniques are based on modifying the Fourier transform of an image operate on the Fourier transform of an image.
基于修改图像的傅里叶变换作用于图像的傅里叶变换。

There are some enhancem ent techniques based on various combinations of methods from these two categories.
有一些基于这两类方法的各种组合的增强技术。

Broad Classes of Image Enhancement Techniques

空间域：（图像平面）
Kōngjiān yù:(Túxiàng píngmiàn)

Spatial Domain: (image plane)

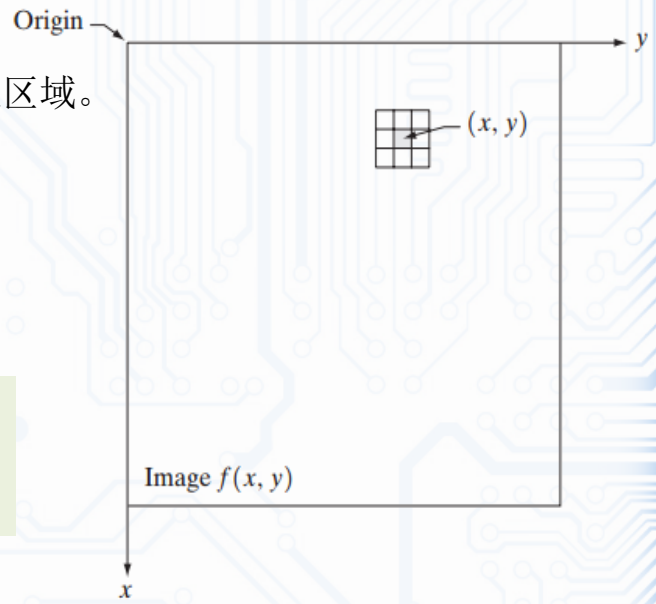
- As indicated previously, the term *spatial domain* refers to the aggregate of pixels composing an image. 如前所述，术语空间域是指构成图像的像素的集合。
- Spatial domain methods are procedures that operate directly on these pixels. 空间域方法是直接在这些像素上操作的过程。
- Spatial domain processes will be denoted by the expression空间域过程将由表达式表示

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

- f(x, y) is the input image
- g(x, y) is the processed image,
- T is an operator on f

Neighbourhood About A Point

关于一个点的邻里 Guānyú yīgè diǎn de línlǐ



定义点(x, y)邻域的主要方法是使用以(x, y)为中心的正方形或矩形子图像区域。

- The principal approach in defining a neighbourhood about a point (x, y) is to use a square or rectangular sub image area centered at (x, y).

The operator T is applied at each location (x, y) to yield the output, g, at that location.

T最简单的形式是邻域大小为1*1(即单个像素)。
在这种情况下，g只依赖于f (x, y)的值，而T则是一个灰度级

- 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

灰度 Huī dù

强度或映射 Qiángdù huò yìngshè

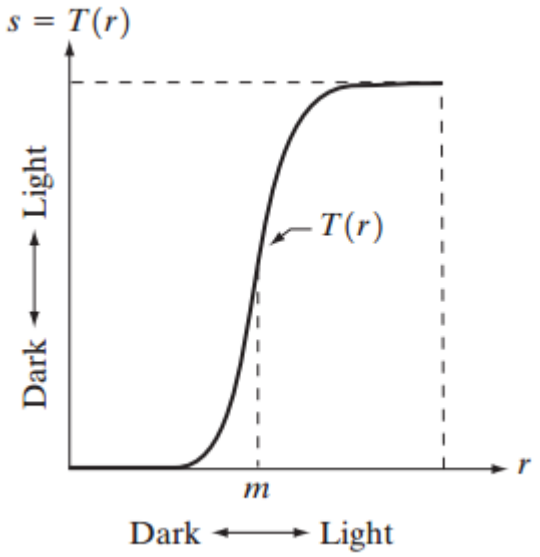
$s = T(r)$

r and s are variables denoting, respectively, the gray level of f(x, y) and g(x, y) at any point (x, y)

contrast stretching

对比拉伸 Duìbǐ lā shēn

For example, if T(r) has the form shown in



- the effect of this transformation would be to produce an image of higher contrast than the original by darkening the levels below *m* and brightening the levels above *m* in the original image.
- In this technique, known as *contrast stretching*, the values of *r* below *m* are compressed by the transformation function into a narrow range of *s*, toward black.

这种变换的效果是通过在原始图像中使m以下的层次变暗，并使m以上的层次变亮，从而产生比原始图像对比度更高的图像。

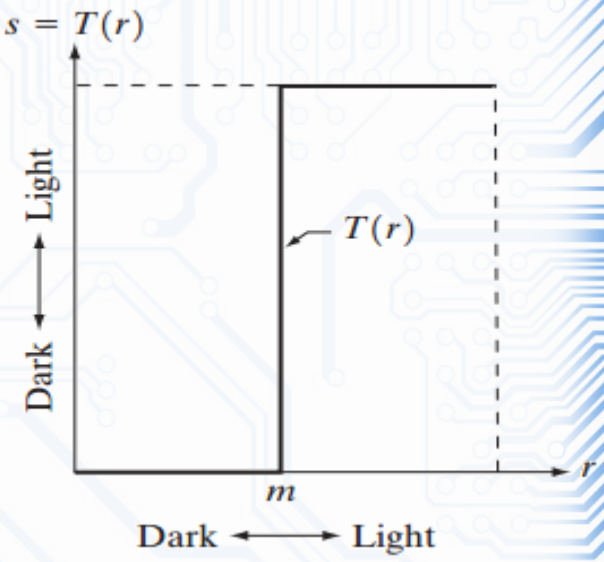
在这种称为对比度拉伸的技术中，r在m以下的值被变换函数压缩到一个狭窄的s范围内，朝向黑色。

thresholding function

阈值函数 Yùzhí hánshù

For example, if T(r) has the form shown in

- The opposite effect takes place for values of r above m. In the limiting case shown in Fig.



- T(r) produces a two-level (binary) image.
- A mapping of this form is called a *thresholding* function.
- 当r大于m时，则会出现相 阈值 Yùzhí 在图中所示的极限情况中。
- T(r)产生两级(二进制)图像。
- 这种形式的映射称为阈值函数。

Main Image Enhancement techniques

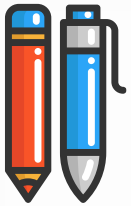
主要图像增强技术 Zhǔyào túxiàng zēngqiáng jìshù

点操作；
直方图均衡和匹配；
基于直方图的增强应用；
Diǎn cāozuò;
zhífāng tú jūnhéng hé pǐpèi;
jīyú zhífāng tú de zēngqiáng yìngyòng;

- Spatial domain techniques
  1. Point operations
  2. Histogram equalization and matching
  3. Applications of histogram-based enhancement

- Frequency domain techniques
  1. Unsharp masking
  2. Homomorphic filtering*

频域技术；
不锐化遮罩；
同态滤波；



The meaning of Good images…..

For human visual

- The visual evaluation of image quality is a highly subjective process.
- It is hard to standardize the definition of a good image.

A certain amount of trial and error usually is required before a particular image enhancement approach is selected.

在选择特定的图像增强方法之前，通常需要进行一定量的反复试验。
Zài xuǎnzé tèdìng de túxiàng zēngqiáng fāngfǎ zhīqián, tōngcháng xūyào jìnxíng yīdìng liàng de fǎnfù shìyàn.

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Image enhancement:

- Point Processing

Point Processing

积分处理 Jīfēn chǔlǐ

- The simplest kind of range transformations are these independent of position x,y:

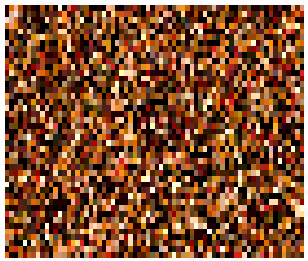
$$g = T(f)$$

- This is called point processing.

- **Important:** every pixel for himself – spatial information completely lost!

Obstacle with point processing
点处理障碍

- Assume that f is the clown image and T is a random function and apply $g = T(f)$:



- What we take from this?
  1. May need spatial information
  2. Need to restrict the class of transformation, e.g. assume monotonicity 需要限制变换的类别，例如假设单调性

Gray Level Transformations

灰度变换 Huī dù biànhuàn

All Image Processing Techniques focused on gray level transformation as it operates directly on pixels. The gray level image involves 256 levels of gray and in a histogram, horizontal axis spans from 0 to 255, and the vertical axis depends on the number of pixels in the image. 所有的图像处理技术都专注于灰度变换，因为它直接对像素进行操作。 灰度图像包含256个灰度等级，在直方图中，水平轴从0到255，垂直轴取决于图像中的像素数。

These are among the simplest of all image enhancement techniques.

- The values of pixels:

  before processing by *r* ,after processing by *s:* s=T(r)

T is a transformation that maps a pixel value *r* into a pixel value *s*.

Since we are dealing with digital quantities, values of the transformation function typically are stored in a one-dimensional array and the mappings from *r* to *s* are implemented via table lookup.由于我们处理的是数字量，转换函数的值通常存储在一维数组中，从r到s的映射是通过表查找实现的。

For an 8-bit environment, a lookup table containing the values of T will have 256 entries.

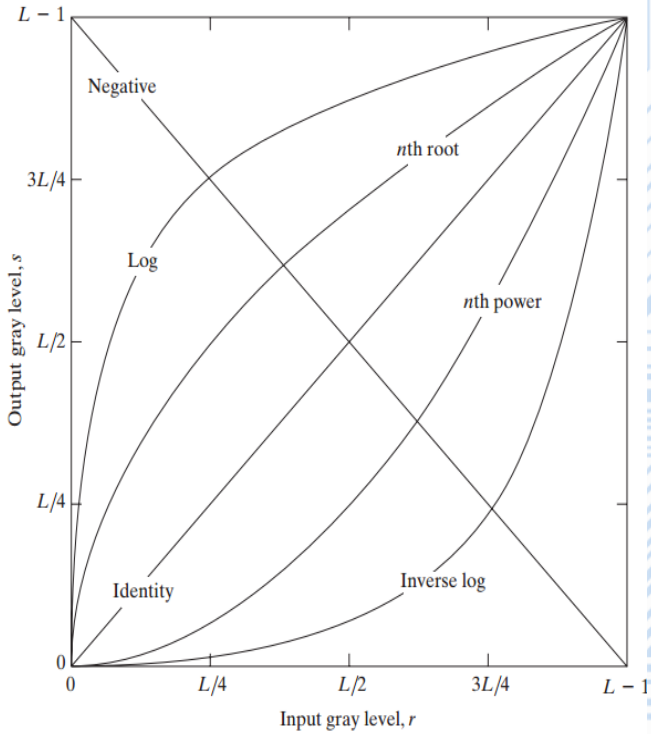
Gray-level Transformations Functions

灰度变换函数 Huī dù biànhuàn hánshù

gray-level transformations, used three basic types of functions used frequently for image enhancement:

- linear **(negative and identity transformations)**
- logarithmic **(log and inverse-log transformations),**
- power-law **(nth power and nth root transformations).**

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



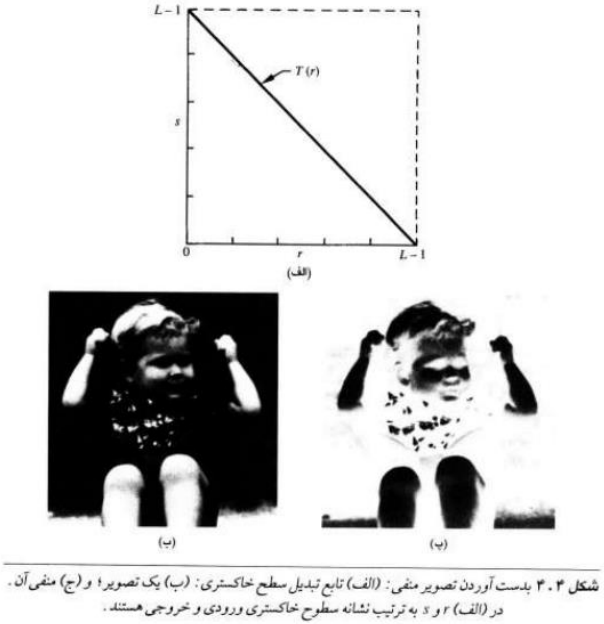
线性（负和恒等变换）；
对数（对数和逆对数变换）；
幂律（n次幂和n次根变换）；
Xiànxìng (fù hé héng děng biànhuàn);
duì shù (duì shù hé nì duì shù biànhuàn);
mì lǜ (n cì mì hé n cì gēn biànhuàn);

Negative

消极的 Xiāojí de

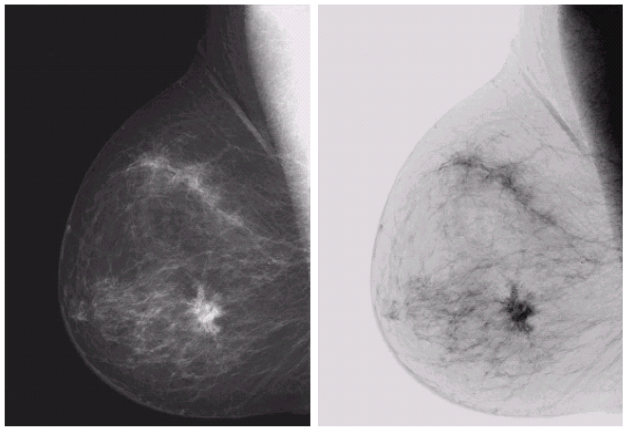
The negative of an image with gray levels in the range [0, L-1] is obtained by using the negative transformation shown in Fig. 3.3, which is given by the expression: $s = L - 1 - r$.

This type of processing is particularly suited for enhancing white or gray detail embedded in dark regions of an image, especially when the black areas are dominant in size



شکل ۳.۴ بدست آوردن تصویر منفی: (الف) تابع تبدیل سطح خاکستری: (ب) یک تصویر؛ و (ج) منفی آن. در (الف) r و s به ترتیب نشانه سطوح خاکستری ورودی و خروجی هستند.

用于增强嵌入在图像黑暗区域的白色或灰色细节，特别是当黑色区域的大小占主导地位时



a b

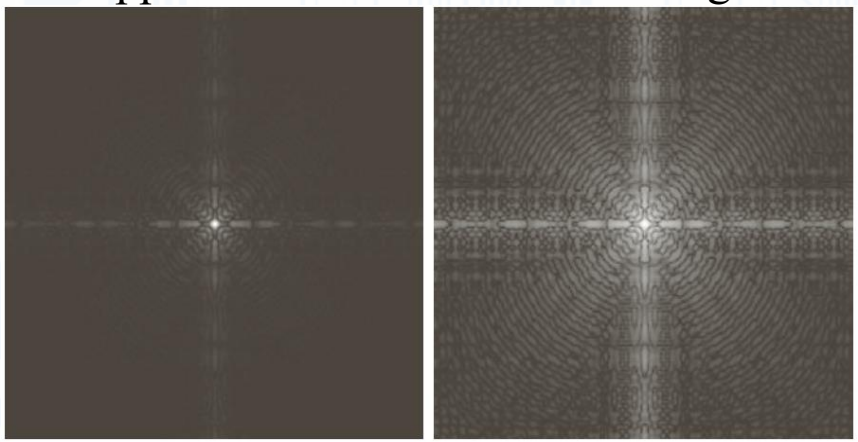
FIGURE 3.4 (a) Original digital mammogram. (b) Negative image obtained using the negative transformation in Eq. (3.2-1). (Courtesy of G.E. Medical Systems.)

Log Transform

对数变换 Duì shù biànhuàn

- **The general form of the log transformation shown in Fig. 3.3 is**
  $s = c \log(1 + r)$
  where *c* is a constant, and it is assumed that r >=0.

- this transformation maps a narrow range of low gray-level values in the input image into a wider range of output levels.这转换将输入图像中较窄范围低灰度值映射到较宽范围的输出级别。
- We would use a transformation of this type to expand the values of dark pixels in an image while compressing the higher-level values. 我们将使用这种类型的转换来扩展图像中深色像素的值，同时压缩更高级别的值。
- The opposite is true of the inverse log transformation.



a b

FIGURE 3.5 (a) Fourier spectrum. (b) Result of applying the log transformation in Eq. (3.2-2) with $c = 1$.

Power-law transformations

幂律变换 Mì lǜ biànhuàn

Power-law transformations have the basic form

$$s = cr^{\gamma} \qquad s = c(r + \varepsilon)^{\gamma}$$

c and g are positive constants.
Second equation is to account for an offset

C和g是正常数。
第二个方程是考虑偏移量

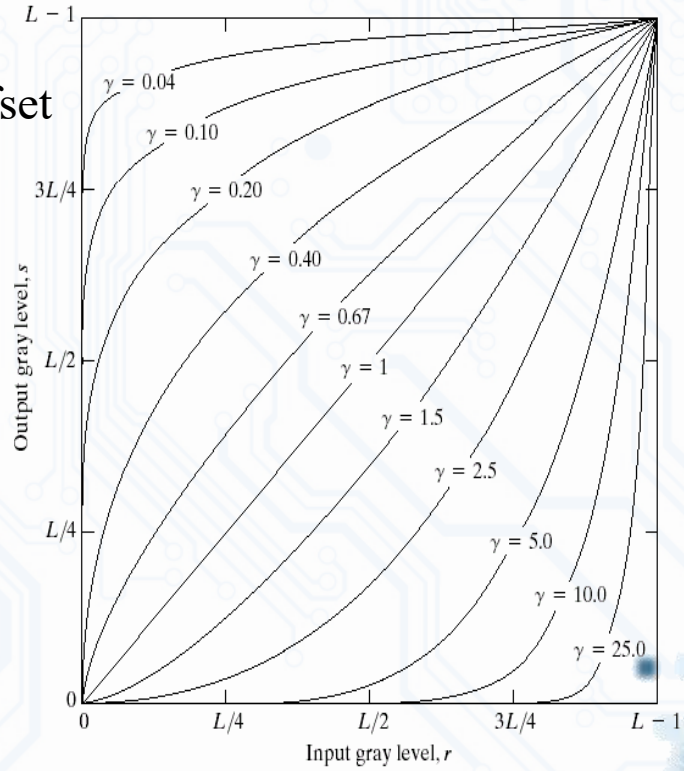


FIGURE 3.6 Plots of the equation $s = cr^{\gamma}$ for various values of γ ($c = 1$ in all cases).

Why power laws are popular?

- A cathode ray tube (CRT), for example, converts a video signal to light in a nonlinear way. The light intensity *I* is proportional to a power (γ) of the source voltage *VS*
- For a computer CRT, γ is about 2.2
- Viewing images properly on monitors requires γ-correction

例如，阴极射线管(CRT)以非线性的方式将视频信号转换成光。 光强I与源电压VS的功率(γ)成正比
对于计算机CRT， γ值约为2.2
在监视器上正确地查看图像需要γ校正

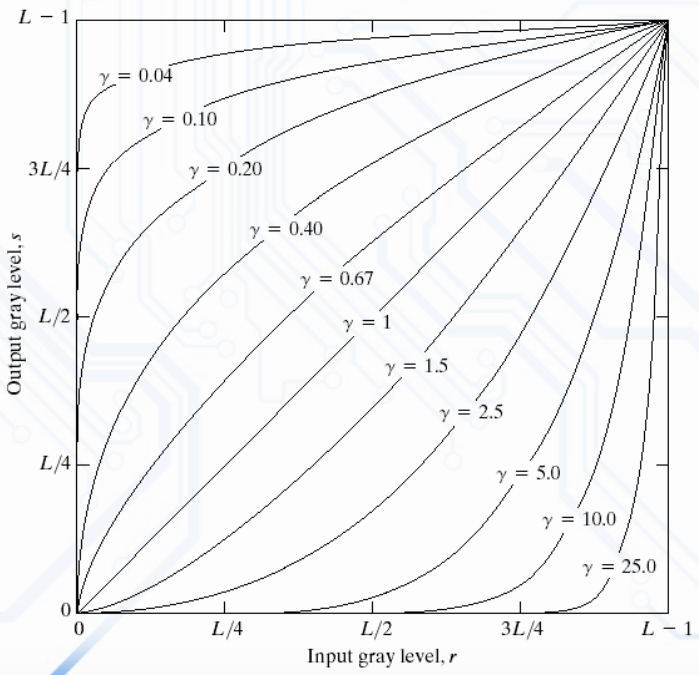
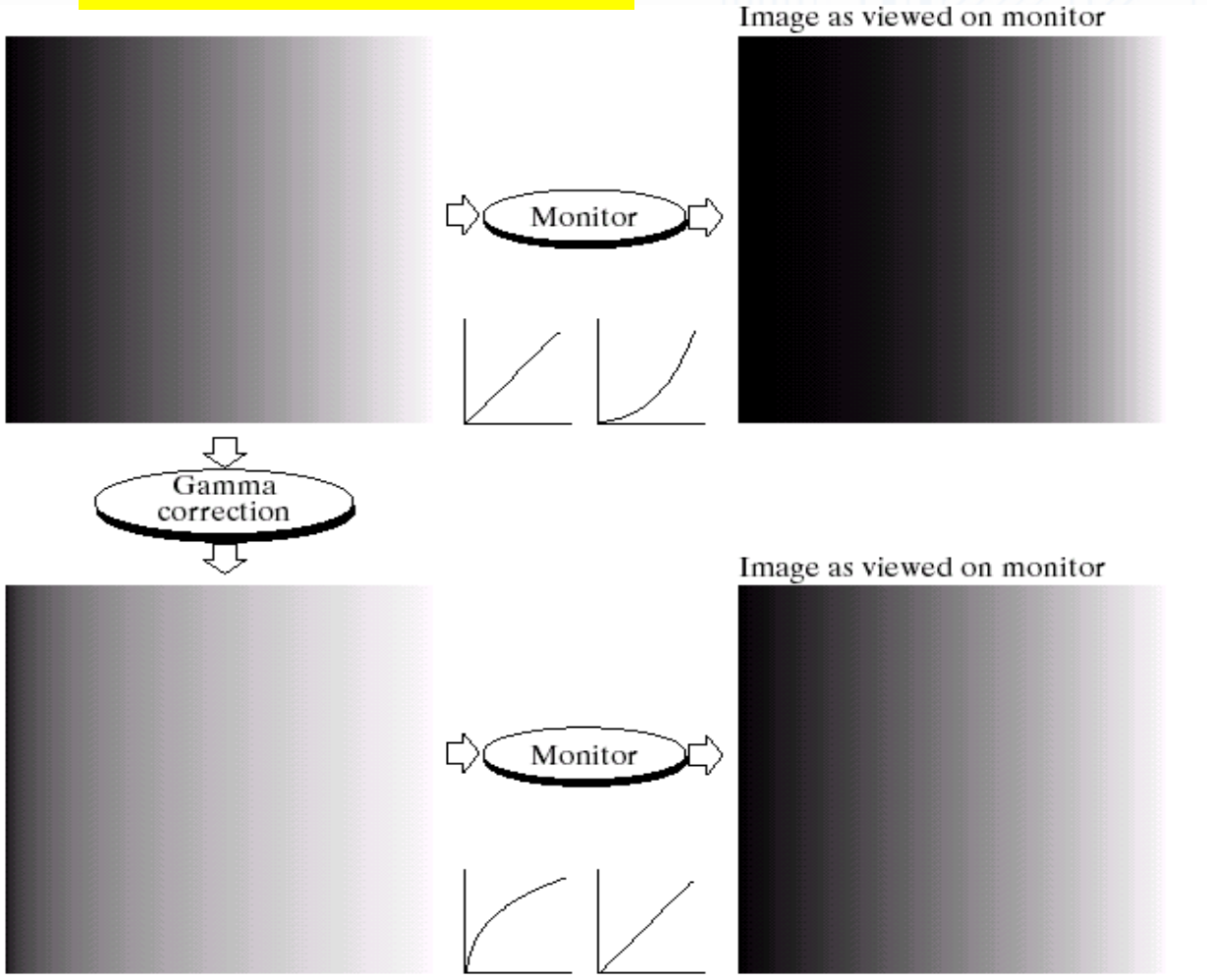


FIGURE 3.6 Plots of the equation $s = cr^{\gamma}$ for various values of γ ($c = 1$ in all cases).

Gamma Correction

伽玛校正 Jiā mǎ jiàozhèng



a b
c d

FIGURE 3.7
(a) Linear-wedge gray-scale image. (b) Response of monitor to linear wedge. (c) Gamma-corrected wedge. (d) Output of monitor.

Gamma Measuring Applet:
http://www.cs.cmu.edu/~efros/java/gamma/gamma.html

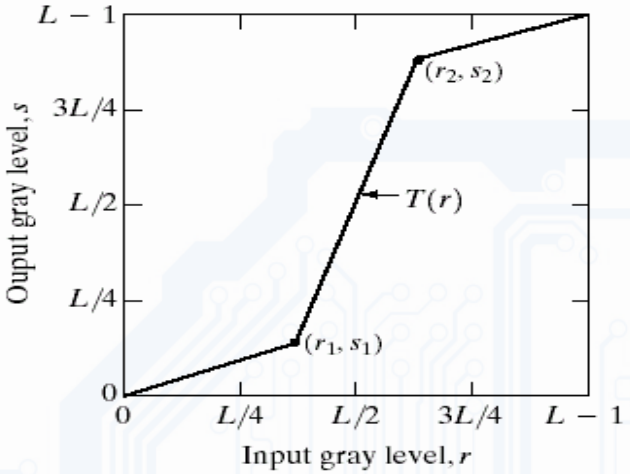
Image Enhancement

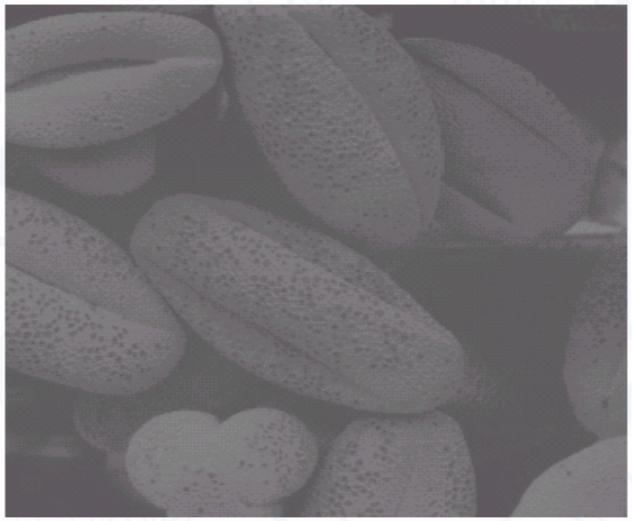
a b
c d

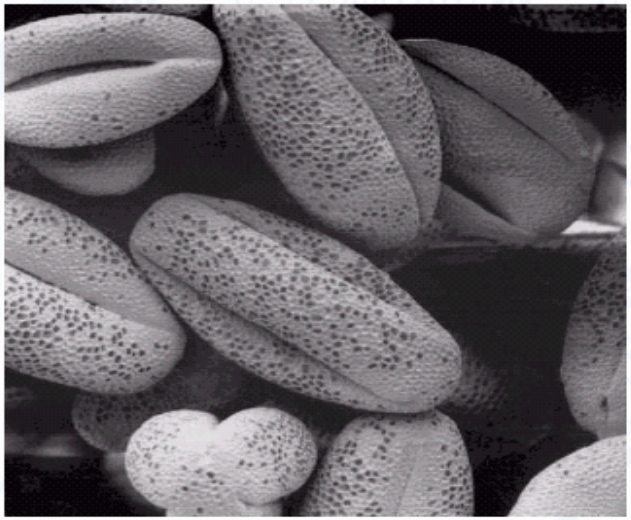
FIGURE 3.9
(a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0, 4.0$, and 5.0, respectively. (Original image for this example courtesy of NASA.)

Contrast Stretching

对比拉伸 Duìbǐ lā shēn







a b
c d

FIGURE 3.10 Contrast stretching. (a) Form of transformation function. (b) A low-contrast image. (c) Result of contrast stretching. (d) Result of thresholding. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

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Image enhancement:

- Histogram Processing

直方图处理 Zhífāng tú chǔlǐ

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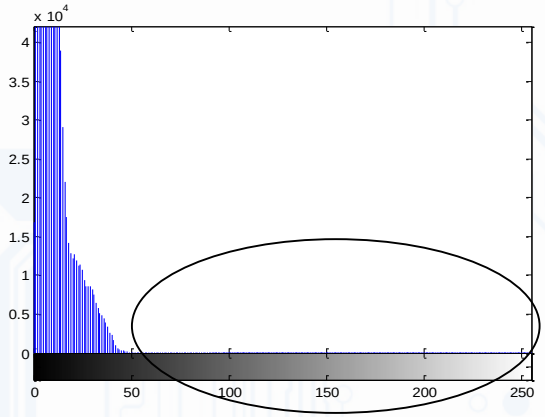
Why Histogram?

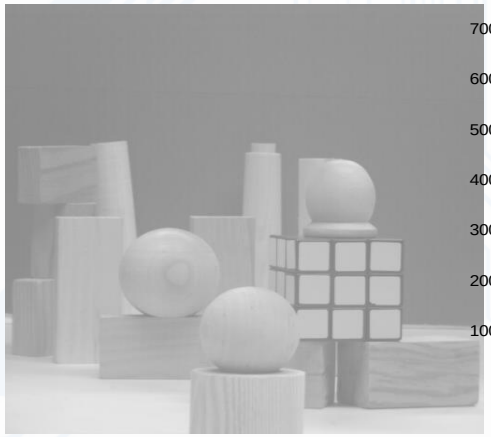
直方图处理 Zhífāng tú chǔlǐ

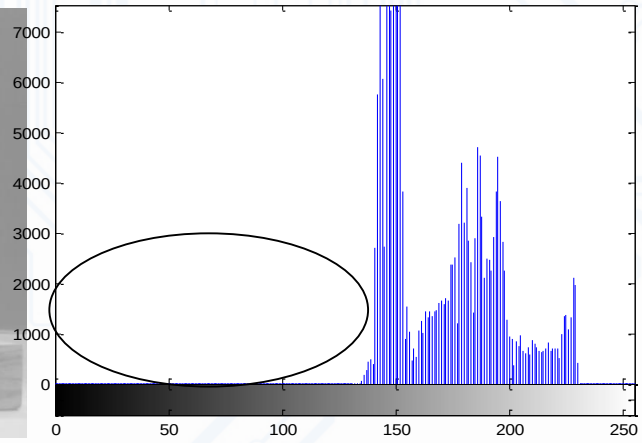


It is a baby in the cradle!

直方图信息显示图像曝光不足

Histogram information reveals that image is under-exposed





Another Example

Over-exposed image

Histogram Processing

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

离散函数

$$h(rk) = n_{k\backslash}$$

Where

- r_k : the k^{th} gray level
- n_k : the number of pixels in the image having gray level r_k
- $h(r_k)$: histogram of a digital image with gray levels r_k

Normalized Histogram

归一化直方图 Guī yī huà zhífāng tú

- dividing each of histogram at gray level r_k by the total number of pixels in the image, n

  将每个直方图在灰度级rk除以图像中的总像素数，n

$$p(rk) = nk/ n$$

For k = 0,1,...,L-1

$p(r_k)$ gives an estimate of the probability of occurrence of gray level r_k

- The sum of all components of a normalized histogram is equal to 1

  归一化直方图所有分量的和等于1

How to Adjust the Image?

- Histogram equalization 直方图均衡 Zhífāng tú jūnhéng
  - Basic idea: find a map f(x) such that the histogram of the modified (equalized) image is flat (uniform).
  - Key motivation: cumulative probability function (cdf) of a random variable approximates a uniform distribution

基本思想:找到一个映射f(x)，使修改(均衡)图像的直方图是平坦的(均匀的)。
主要动机:随机变量的累积概率函数(cdf)近似于均匀分布

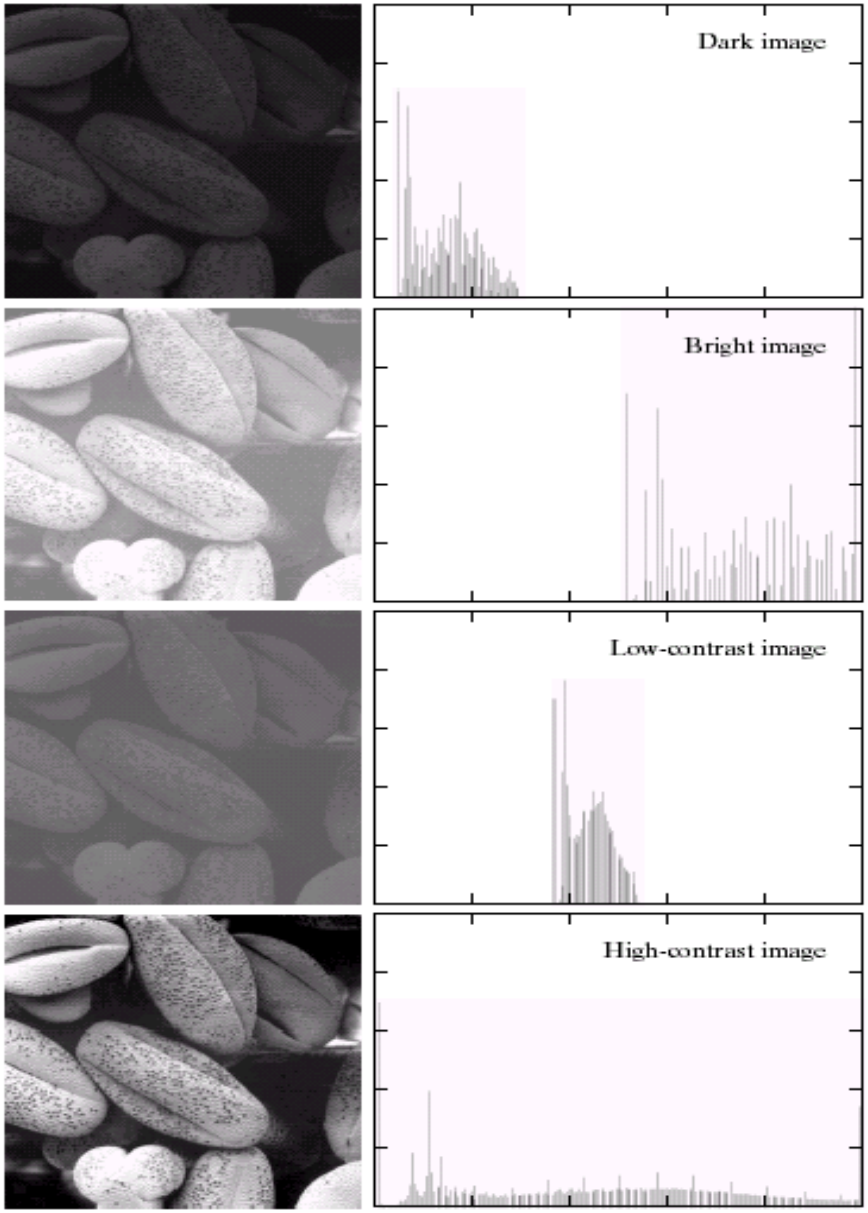
Suppose h(t) is the histogram (pdf)

probability density function (PDF)

$$s(x) = \sum_{t=0}^{x} h(t)$$

概率密度函数 (PDF) Gàilǜ mìdù hánshù (PDF)

Image Histograms



Components of histogram are concentrated on the low side of the gray scale

x-axis – values of intensities
y-axis – their frequencies 频率

Components of histogram are concentrated on the high side of the gray scale

Histogram is narrow and concentrated toward the middle of the gray scale

Histogram covers wide range of the gray scale and the distribution is nearly uniform over the entire gray scale except at few points near the dark region of the gray scale

a b

FIGURE 3.15 Four basic image types: dark, light, low contrast, high contrast, and their corresponding histograms. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

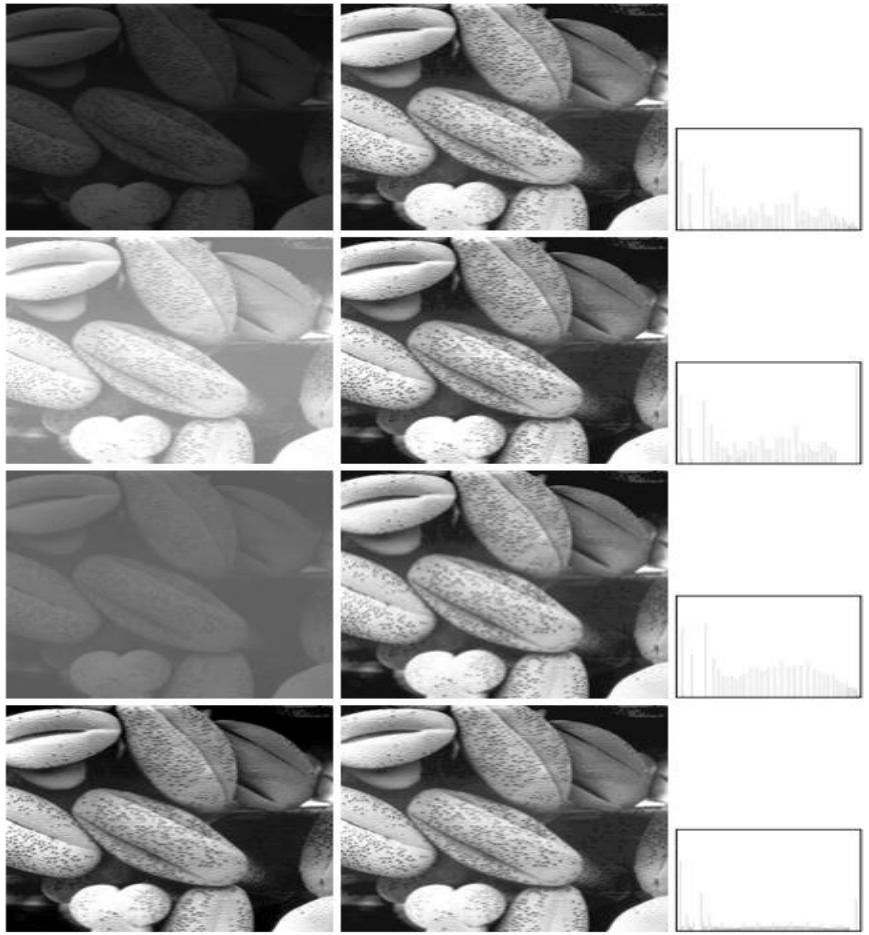
histogram matching or *histogram specification*.

直方图匹配或直方图规范。 Zhífāng tú pǐpèi huò zhífāng tú guīfàn.

- In particular, it is useful sometimes to be able to specify the shape of the histogram that we wish the processed image to have.
- The method used to generate a processed image that has a specified histogram is called *histogram matching* or *histogram specification*.

特别是，有时能够指定我们希望处理的图像具有的直方图的形状是很有用的。

用于生成具有指定直方图的已处理图像的方法称为直方图匹配或直方图规范。

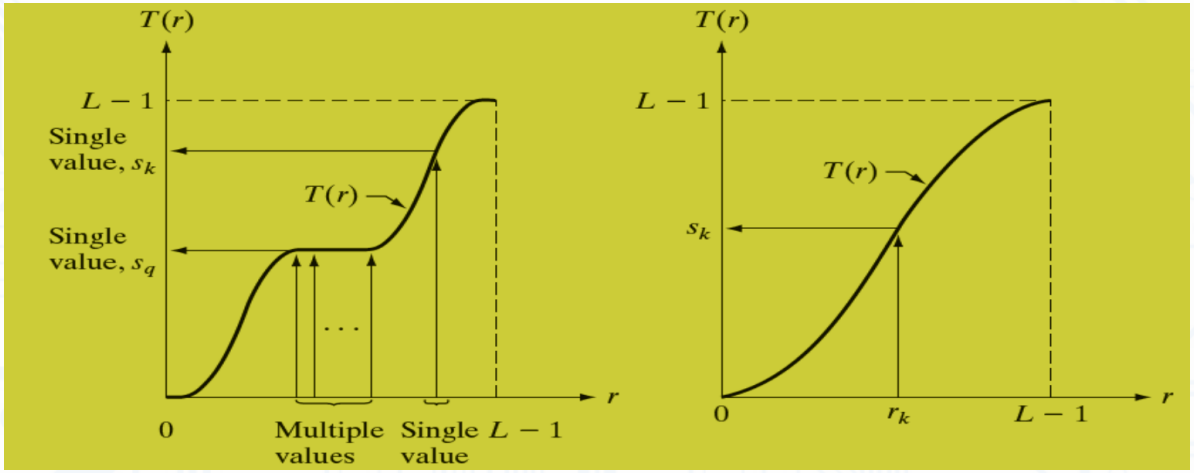


a b c

FIGURE 3.17 (a) Images from Fig. 3.15. (b) Results of histogram equalization. (c) Corresponding histograms.

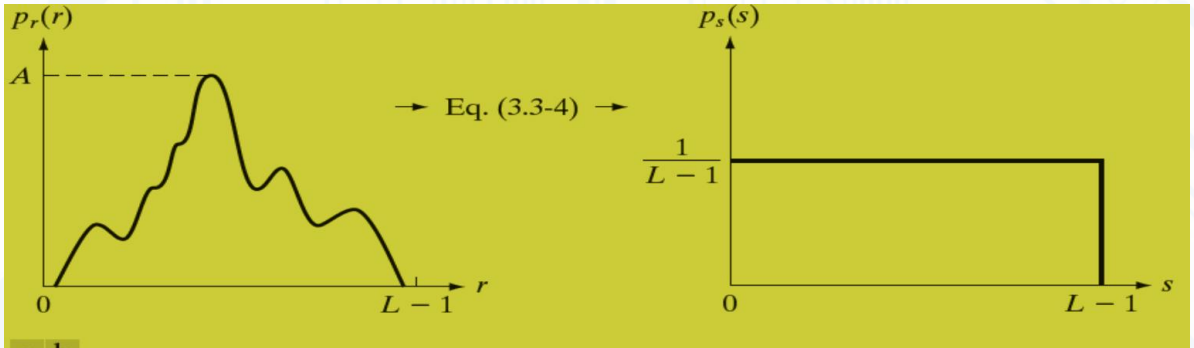
Histogram Equalization (Idea)

- Idea: apply a monotone transform resulting in an approximately uniform histogram想法:应用单调变换得到近似均匀的直方图



a b

FIGURE 3.17 (a) Monotonically increasing function, showing how multiple values can map to a single value. (b) Strictly monotonically increasing function. This is a one-to-one mapping, both ways.



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

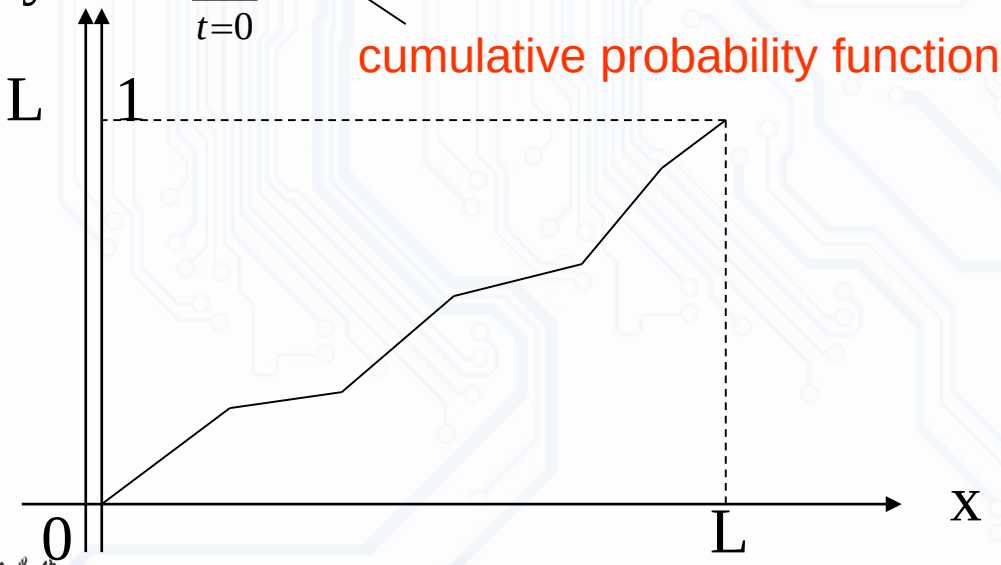
$$y = L \cdot \sum_{t=0}^{x} h(t)$$

Uniform Quantization

Note: $\sum_{t=0}^{L} h(t) = 1$

$$s = \sum_{t=0}^{x} h(t)$$

cumulative probability function



Histogram Equalization

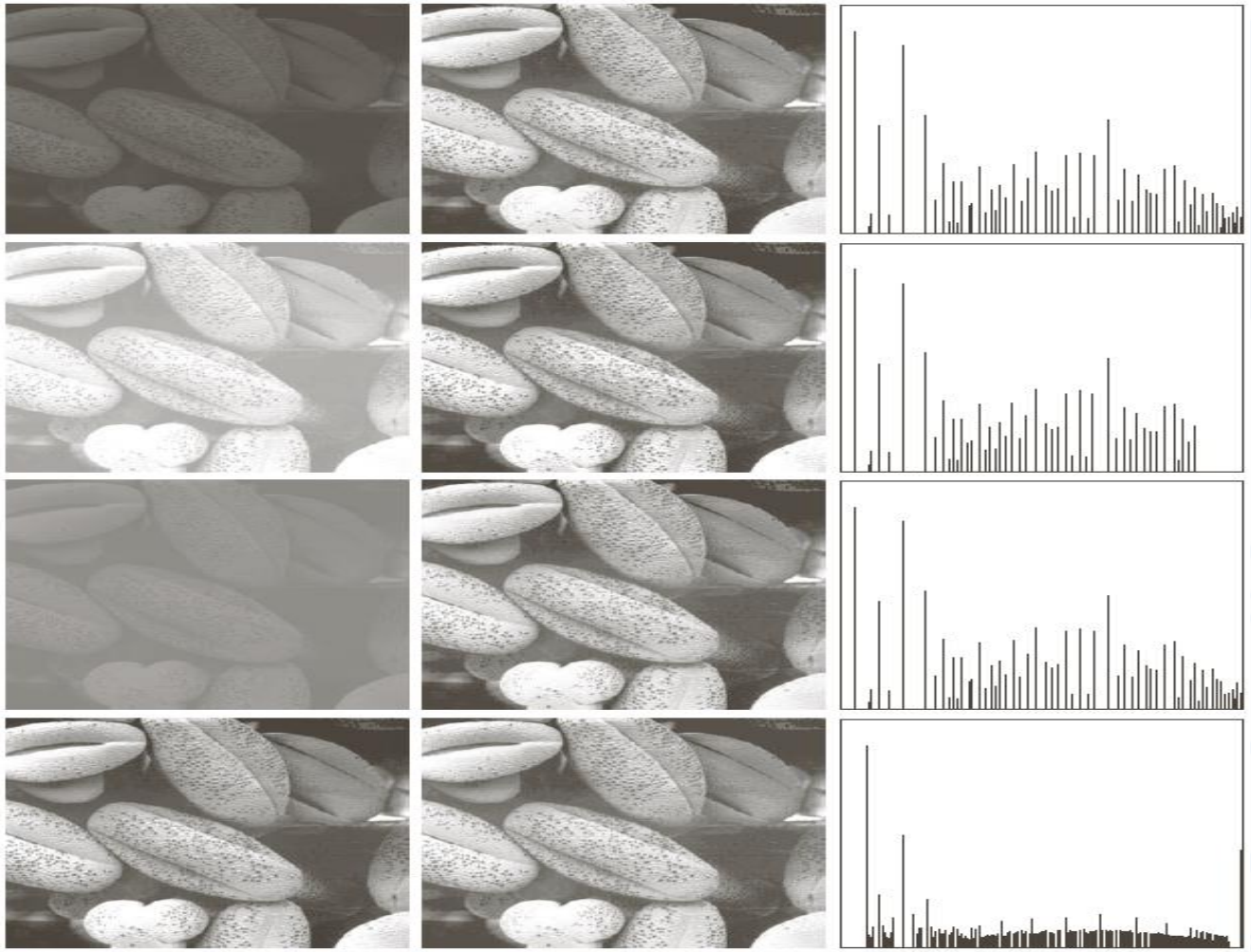


FIGURE 3.20 Left column: images from Fig. 3.16. Center column: corresponding histogram-equalized images. Right column: histograms of the images in the center column.

Histogram Equalization

Let r represent the input gray levels in the interval [0,1] where r=0 represents black and r=1 represents white. 设r表示区间[0,1]的输入灰度，其中r=0表示黑色，r=1表示白色。

The transformation

$s=T(r)$

产生一个灰度级，s在输出图像中对应每个灰度级，r在原始(输入)图像中。 这种变换是为了满足以下条件:

produces a gray level, s in the output image for every gray level, r in the original (input) image.

This transformation is to satisfy the following conditions:

a) **T(r) is single-valued, monotonically increasing in the interval 0<r<1**

b) **(b) 0<T(r)<1 for 0<r<1**

Condition

(a) **preserves the order when r varies from black to white and** 保持r从黑到白的顺序

(b) **guarantees a mapping that is consistent with the allowed range of pixel values.**保证映射与允许的像素值范围一致。

Histogram Equalization

直方图均衡 Zhífāng tú jūnhéng

- Single-valued function, T(r) guarantees that there exists an inverse transformation

$$r = T^{-1}(s)$$

that satisfies the same set of conditions (a) and (b).

若pr(r)表示随机变量s的概率密度函数，r和ps(s)表示随机变量s的概率密度函数，则根据基本概率

- **If $p_r(r)$ represents the probability density function (PDF) of the random variable, r and $p_s(s)$ represents the probability density function (PDF) of the random variable, s, then from the basic probability theory,**

$$p_s(s) = \left[p_r(r) \frac{dr}{ds} \right]_{r=T^{-1}(s)}$$

Histogram Equalization

- Histogram equalization is to control the PDF (probability density function)of gray levels of an image via a transformation function so that the resulting PDF is a uniform density. 直方图均衡化是通过变换函数控制图像灰度级的概率密度函数(PDF)，使得到的PDF具有均匀的密度。

- This is achieved by taking the cumulative distribution function (CDF) of r as the required transformation function, T(r) i.e.,

$$s = T(r) = \int_0^r p_r(w)\,dw$$

where w is the dummy variable of integration.

Histogram Equalization

- With this transformation function, the PDF, $p_s(s)$ of s becomes

$$\frac{ds}{dr} = \frac{dT(r)}{dr}$$

$$= \frac{d}{dr}\left[\int_0^r p_r(w)dw\right]$$

$$= p_r(r)$$

$$p_s(s) = p_r(r)\left|\frac{dr}{ds}\right|$$

$$= p_r(r)\left|\frac{1}{p_r(r)}\right|$$

$$= 1 \quad \text{where } 0 \le s \le 1$$

Substitute and yield

Histogram Equalization- Discrete Form

The probability of occurrence of gray level in an image is approximated by

$$p_r(r_k) = \frac{n_k}{n} \qquad where\ k = 0, 1, ..., L-1$$

The discrete version of transformation

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

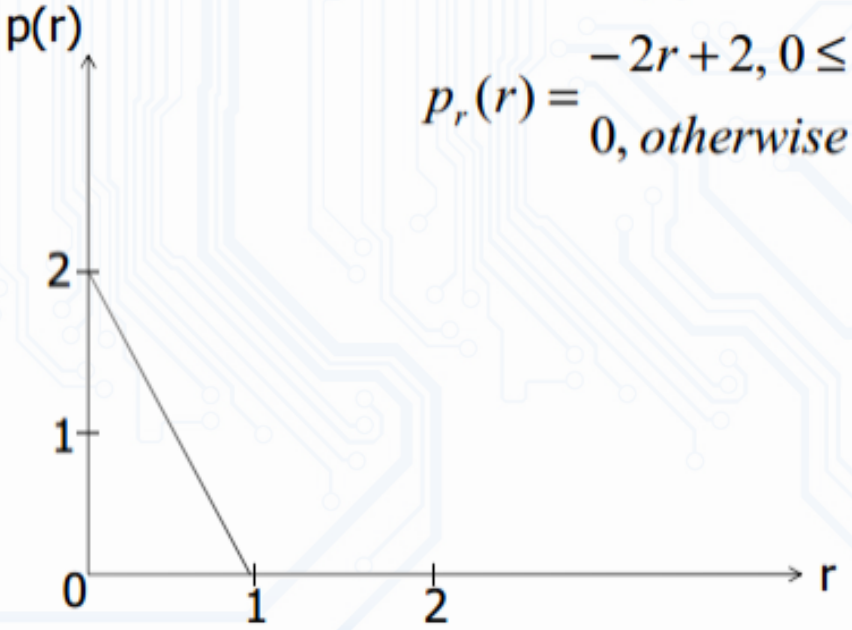
$$= \sum_{j=0}^{k} \frac{n_j}{n} \qquad where\ k = 0, 1, ..., L-1$$

Histogram Equalization- Discrete Form

Thus, the histogram equalization or linearization is a method of obtaining a uniform histogram for a given image.

因此，直方图均衡化或线性化是一种获得给定图像的均匀直方图的方法。

Histogram Equalization-Example



$$p_r(r) = \begin{cases} -2r+2, 0 \le r \le 1 \\ 0, otherwise \end{cases}$$

Histogram Equalization- Example

- Hence, the required transformation function is

$$s = T(r) = \int_0^r p_r(w)\,dw = \int_0^r (-2w+2)\,dw = -r^2 + 2r$$

- Solving the above equation for r, we have

$$r = T^{-1}(s) = 1 \pm \sqrt{(1-s)}$$

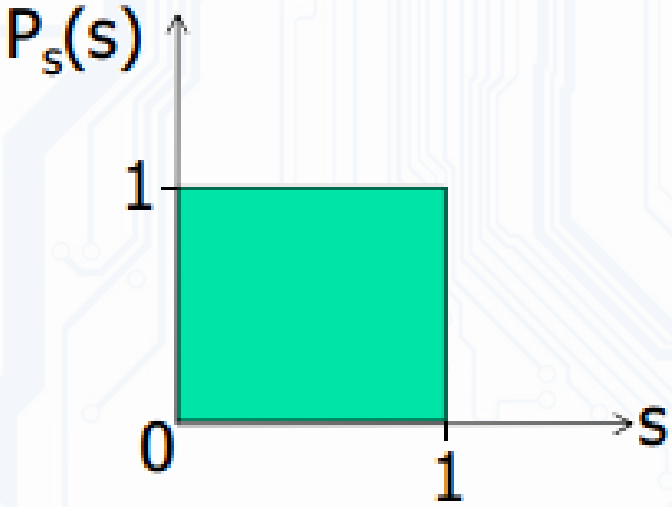
- Since r lies in the interval [0,1], only the function is valid.

$$r = T^{-1}(s) = 1 - \sqrt{(1-s)}$$

Histogram Equalization- Example

- Hence,

$$p_s(s) = \left[p_r(r) \frac{dr}{ds} \right]_{|r=T^{-1}(s)=1-\sqrt{(1-s)}} = \left[(-2r+2) \frac{d}{ds} [1-\sqrt{(1-s)} \right]$$



$$= \left[(2\sqrt{(1-s)}) \left(\frac{1}{2} \right) \left[\frac{1}{\sqrt{(1-s)}} \right] \right]$$

$$= 1, \; for \; 0 \le s \le 1$$

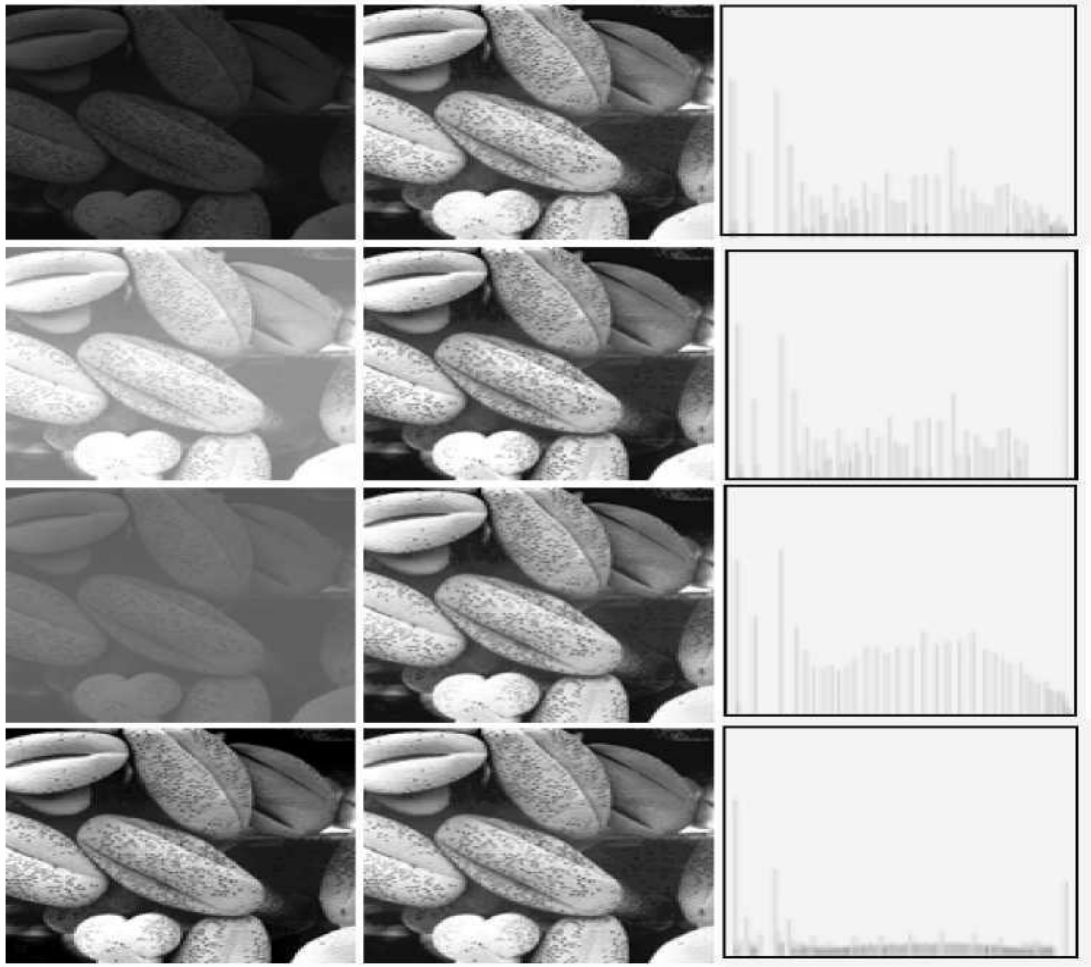
Histogram Equalization

Dark image

Bright image

Low-contrast image
低反差的

High-contrast image



Histogram Specification

- Histogram specification is a method of obtaining a particular histogram shape capable of highlighting certain gray level ranges in a given image.
- 直方图规范是一种获取特定直方图形状的方法，能够在给定的图像中突出显示特定的灰度范围。

Histogram Specification

- If $p_r(r)$ and $p_s(s)$ represent the original and desired probability density functions, respectively, then the histogram specification is achieved as follows:

1. Equalize the levels of the original image via the transformation function

$$s = T(r) = \int_0^r p_r(w)\, dw$$

2.Specify the desired probability density function, $p_z(z)$ and obtain the transformation function

$$s = G(z) = \int_0^{\bar{z}} p_z(w)\, dw$$

3.Apply the inverse transformation $z=G^{-1}(s)$ to the levels equalized in step 1.

Histogram Specification

The resulting image has the gray levels characterized by the specified probability density function, $p_z(z)$ i.e., has the specified histogram.

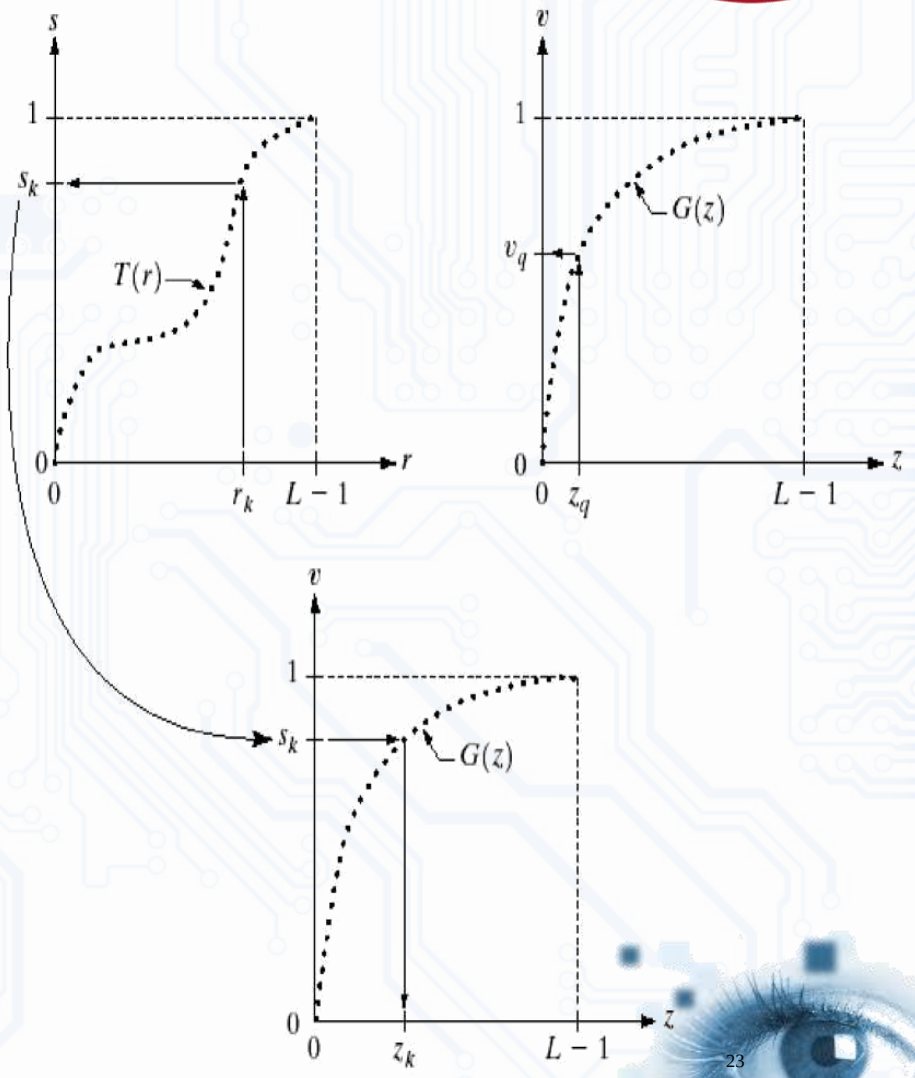
得到的图像具有由指定的概率密度函数pz(z)表征的灰度级，即具有指定的直方图。

- In practice, the inverse transformation from s to z is not single-valued. This happens when there are unfilled levels in the specified histogram.

实际上，从s到z的逆变换不是单值的。 当指定的直方图中有未填充的水平时，就会发生这种情况。

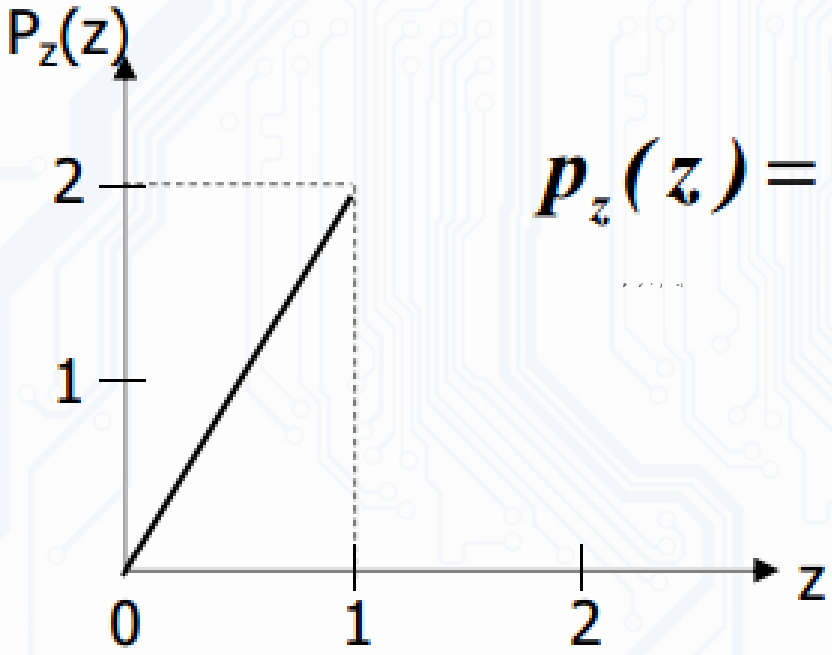
- These unfilled levels make the cumulative distribution function to be constant over the unfilled intervals.

这些未填充的能级使累积分布函数在未填充的区间内保持恒定。



Histogram Specification- Example

- We would like to apply the histogram specification with the desired probability density function $p_z(z)$ as shown.

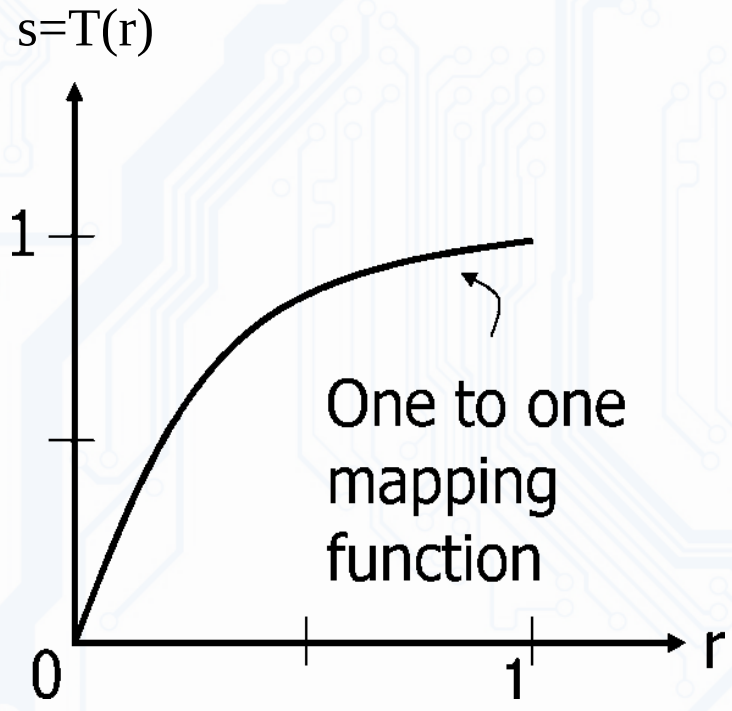


$$p_z(z) = \begin{cases} 2z & ;0 \le z \le 1 \\ 0 & ;\text{elsewhere} \end{cases}$$

$$\int_0^z p_z(w)dw = 1$$

Step 1

Obtain the transformation function T(r)



$$s = T(r) = \int_0^r p_r(w)\,dw$$

$$= \int_0^r (-2w + 2)\,dw$$

$$= -w^2 + 2w\Big|_0^r$$

$$= -r^2 + 2r$$

Step 2

- Obtain the transformation function G(z)

$$G(z) = \int_0^z (2w)dw \qquad = z^2\Big|_0^z \qquad = z^2$$

Step 3

- Obtain the inversed transformation function G^{-1}

$$G(z) = T(r)$$

$$z^2 = -r^2 + 2r$$

$$z = \sqrt{2r - r^2}$$

- We can guarantee that $0 \leq z \leq 1$ when $0 \leq r \leq 1$

Local Enhancement

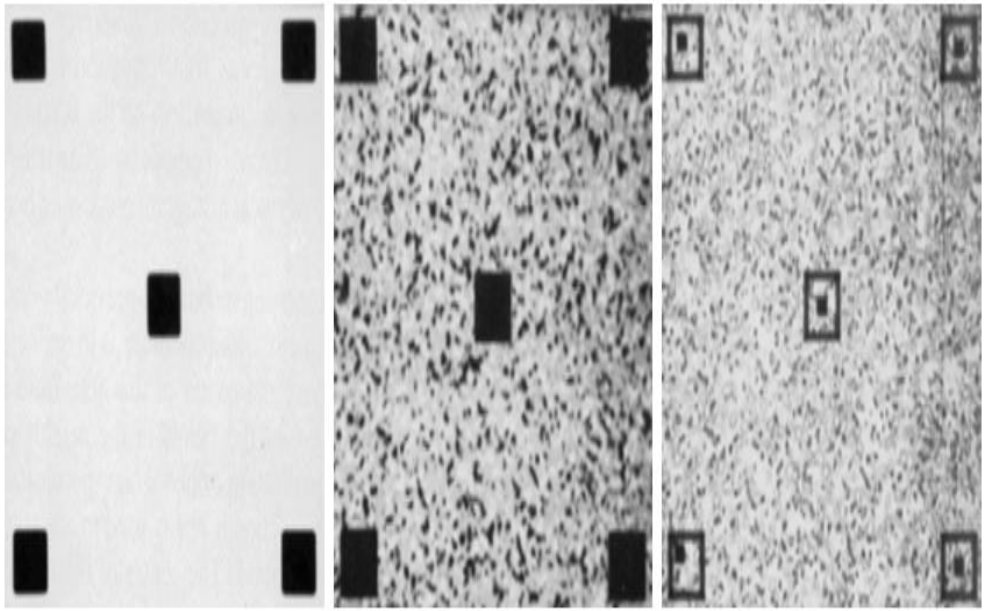
- the histogram processing methods are global, in the sense that pixels are modified by a transformation function based on the gray-level content of an entire image.
- Although this global approach is suitable for overall enhancement, there are cases in which it is necessary to enhance details over small areas in an image.
- The number of pixels in these areas may have negligible influence on the computation of a global transformation whose shape does not necessarily guarantee the desired local enhancement.
- The solution is to devise transformation functions based on the gray-level distribution—or other properties—in the neighborhood of every pixel in the image.
- 直方图处理方法是全局的，即基于整幅图像的灰度内容通过变换函数修改像素。
- 尽管这种全局方法适用于整体增强，但在某些情况下，有必要增强图像中小区域的细节。
- 这些区域的像素数量对全局变换的计算影响可以忽略不计，因为全局变换的形状不一定能保证期望的局部增强。
- 解决方案是根据图像中每个像素附近的灰度分布或其他性质设计变换函数。

Local Enhancement

- The global histogaram can be used locally by to define a square or rectangular neighborhood and move the center of this area from pixel to pixel. At each location, the histogram of the points in the neighborhood is computed and either a histogram equalization or histogram specification transformation function is obtained.
- This function is finally used to map the gray level of the pixel centered in the neighborhood.The center of the neighborhood region is then moved to an adjacent pixel location and the procedure is repeated. Since only one new row or column of the neighborhood changes during a pixel-to-pixel translation of the region, updating the histogram obtained in the previous location with the new data introduced at each motion step is possible
- 全局直方图可用于局部定义一个正方形或矩形邻域，并将该区域的中心从一个像素移动到另一个像素。 在每个位置，计算邻域点的直方图，得到直方图均衡化或直方图规范变换函数。
- 最后用这个函数来映射以邻域为中心的像素的灰度。 然后将邻域的中心移动到相邻的像素位置，重复上述过程。 由于在该区域的像素到像素的平移过程中，只有一个新的邻域行或列发生变化，因此在每个运动步骤中引入的新数据可以更新在之前位置获得的直方图

Local Enhancement

局部增强 Júbù zēngqiáng



a b c

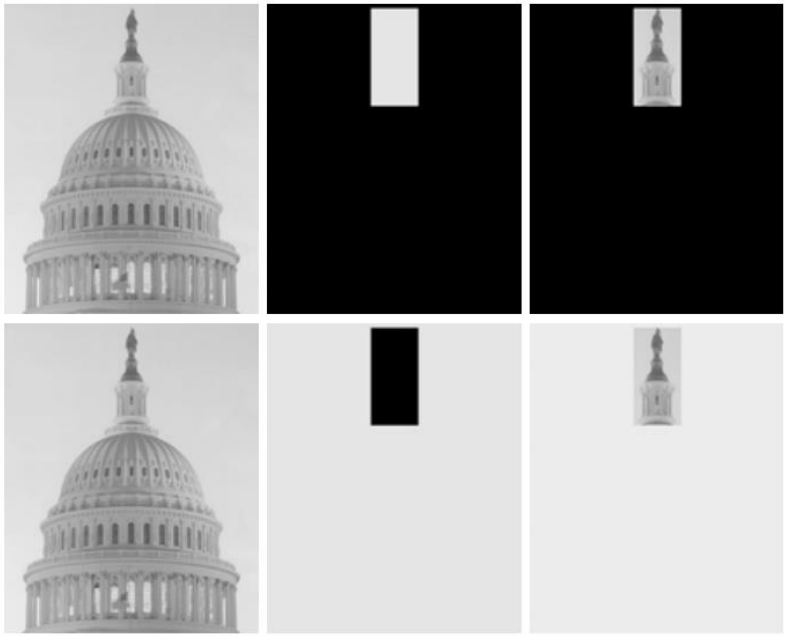
FIGURE 3.23 (a) Original image. (b) Result of global histogram equalization. (c) Result of local histogram equalization using a 7 × 7 neighborhood about each pixel.

Figure 3.23(a) shows an image that has been slightly blurred to reduce its
noise content
Figure 3.23(b) shows the result of global histogram equalization.
As is often the case when this technique
is applied to smooth, noisy areas, Fig. 3.23(b) shows considerable enhancement
of the noise, with a slight increase in contrast.
图3.23(a)显示了稍微模糊的图像，以减少它
噪声内容
图3.23(b)为全局直方图均衡化结果。
这是这种技术经常出现的情况
图3.23(b)显示了显著的增强
与噪声的对比略有增加。

Enhancement Using Arithmetic/Logic Operations

使用算术/逻辑运算增强 Shǐyòng suànshù/luójí yùnsuàn zēngqiáng

- Arithmetic/logic operations involving images are performed on a pixel-by-pixel basis between two or more images (this excludes the logic operation NOT, which is performed on a single image).涉及图像的算术/逻辑操作是在两个或多个图像之间逐像素执行的(这排除了逻辑操作NOT，它是在单个图像上执行的)。



a b c
d e f

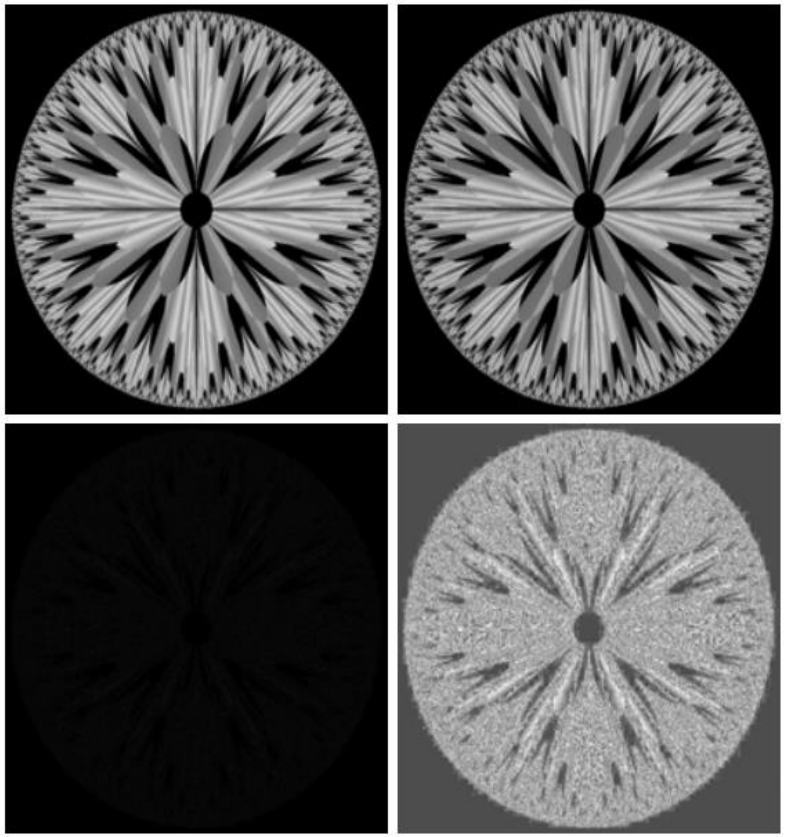
FIGURE 3.27 (a) Original image. (b) AND image mask. (c) Result of the AND operation on images (a) and (b). (d) Original image. (e) OR image mask. (f) Result of operation OR on images (d) and (e).

subtraction of two images results in a new image whose pixel at coordinates (x, y) is the difference between the pixels in that same location in the two images being subtracted.

Logic operations similarly operate on a pixel-by-pixel basis. We need only be concerned with the ability to implement the AND, OR, and NOT logic operators because these three operators are *functionally complete*

In the AND and OR image masks, light represents a binary 1 and dark represents a binary 0.
Masking sometimes is referred to as region of interest (ROI) processing.

- Of the four arithmetic operations, subtraction and addition (in that order) are the most useful for image enhancement.在四种算术运算中，减法和加法(按此顺序)对图像增强最有用。
- We consider division of two images simply as multiplication of one image by the reciprocal of the other.我们把两个图像的除法简单地看作是一个图像乘以另一个图像的倒数。



a b
c d

FIGURE 3.28
(a) Original fractal image. (b) Result of setting the four lower-order bit planes to zero. (c) Difference between (a) and (b). (d) Histogram-equalized difference image. (Original image courtesy of Ms. Melissa D. Binde, Swarthmore College, Swarthmore, PA).

Image Averaging

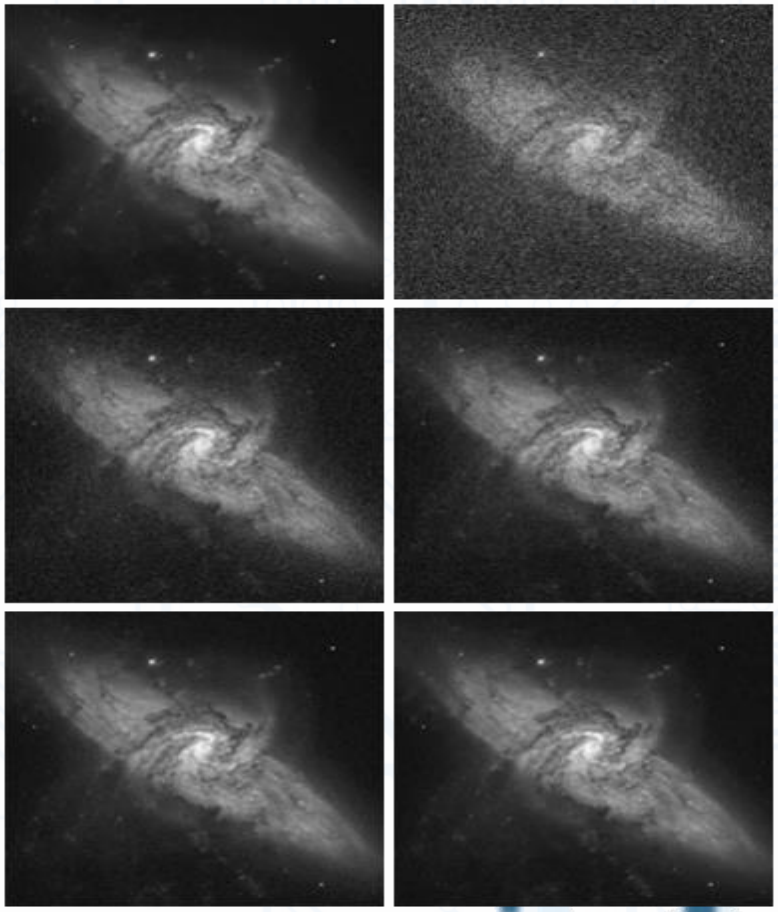
图像平均 Túxiàng píngjūn

- Consider a noisy image g(x, y) formed by the addition of noise h(x, y) to an original image f(x, y); that is, g(x, y) = f(x, y) + h(x, y)

  where the assumption is that at every pair of coordinates (x, y) the noise is uncorrelated† and has zero average value

考虑在原始图像f(x, y)上加入噪声h(x, y)形成的噪声图像g(x, y); 即g(x, y) = f(x, y) + h(x, y)

假设在每一对坐标(x, y)噪声是不相关的和有零平均值

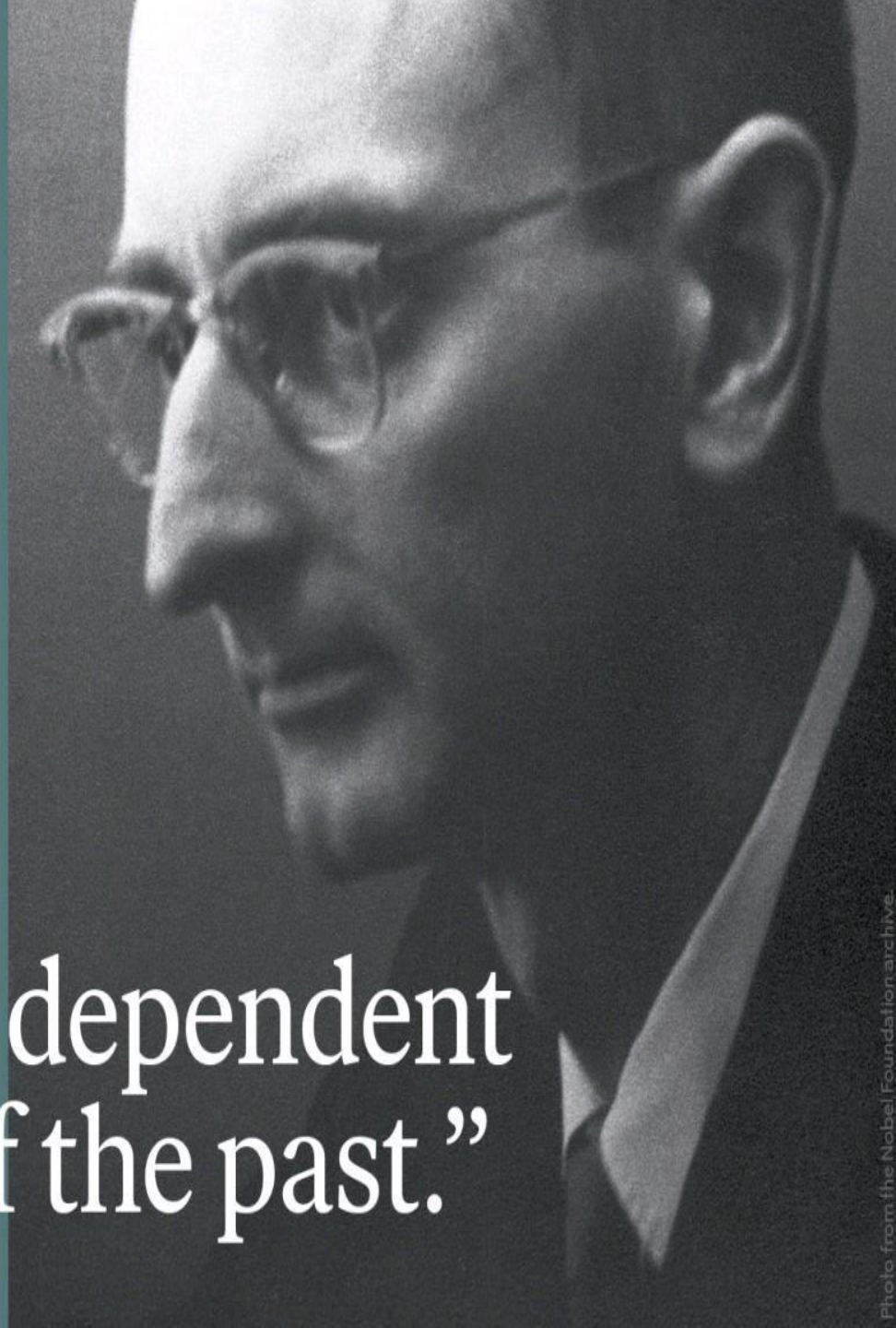


a b
c d
e f

FIGURE 3.30 (a) Image of Galaxy Pair NGC 3314. (b) Image corrupted by additive Gaussian noise with zero mean and a standard deviation of 64 gray levels. (c)–(f) Results of averaging $K = 8, 16, 64$, and 128 noisy images. (Original image courtesy of NASA.)

"I cannot
teach anybody
anything,
I can only
make them think."
~Socrates

OWEN CHAMBERLAIN
Nobel Prize in Physics 1959



"Each new idea is dependent upon the ideas of the past."

Student Task_3: DIP

- 请帮我翻译部分的朋友鼓掌
- Qǐng bāng wǒ fānyì bùfèn de péngyǒu gǔzhǎng

Solve the Question shared in mooc

解决mooc分享的问题

Send for Next lecture

发送下一个讲座

Reference

Introduction to MATLAB, *Kadin Tseng,Boston University, Scientific Computing and Visualization*

- Images taken from Gonzalez & Woods, Digital Image Processing (2002)

江西理工大学
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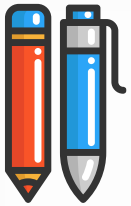
信息工程学院
School of information engineering

Digital Image Processing

THANK YOU



"BE HUMBLE. BE HUNGRY. AND ALWAYS BE THE HARDEST WORKER IN THE ROOM."