第三章

灰度变换与空间滤波

3. Intensity transformations & spatial filtering

- Background
- Some basic intensity transformation
- Histogram-based image processing
- Fundamentals of spatial filtering
- Smoothing spatial filters
- Sharpen spatial filters

3.1 Background

- 灰度变换与空间滤波均是在空间域操作——直接对图像像素进行
  - 灰度变换在图像的单个像素上操作，主要以对比度和阈值处理为目的
  - 空间滤波涉及改善性能的操作（邻域操作），如通过图像中每一个像素的邻域处理来锐化图像

图像增强

3.1 Background

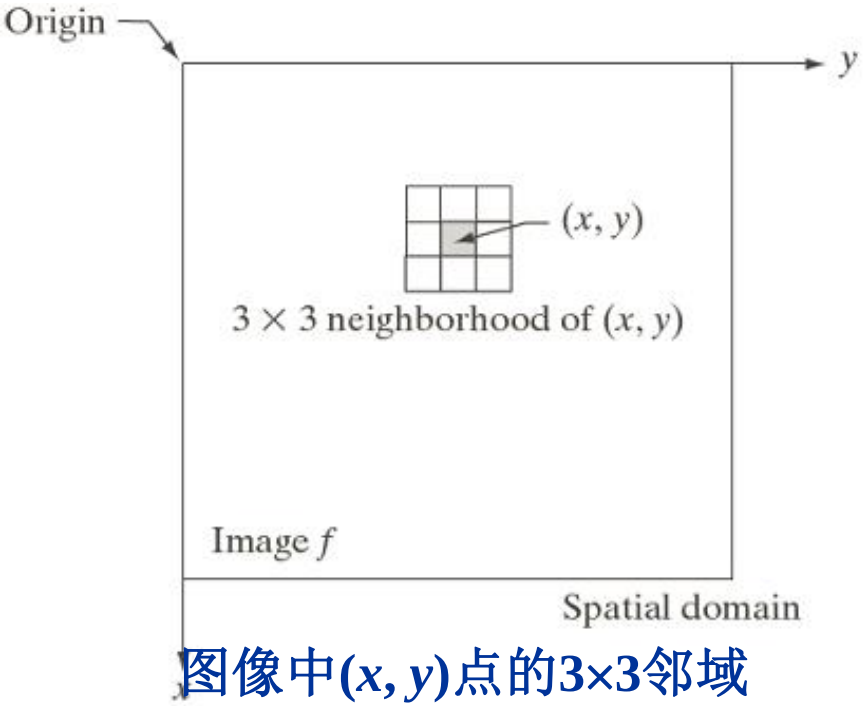
- **The general form of spatial domain processes**
  - **Given the gray level of a pixel, use a function T to output a modified gray level**

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

  - $f(x,y)$: 输入图像
  - $g(x,y)$: 增强后的图像
  - $T[\bullet]$: 定义在(x,y)邻域的算子

3.1 Background

- **像素(x, y)的邻域: 通常定义为以(x, y)为中心的矩形(正方形居多)的子图像**



图像中(x, y)点的3×3邻域

- **The neighborhood size**
  1. 邻域为1×1: Basic intensity transformation
  2. 邻域$n \times n$: 基于空间滤波的增强
  3. 整幅图像的统计特性: 基于直方图的增强

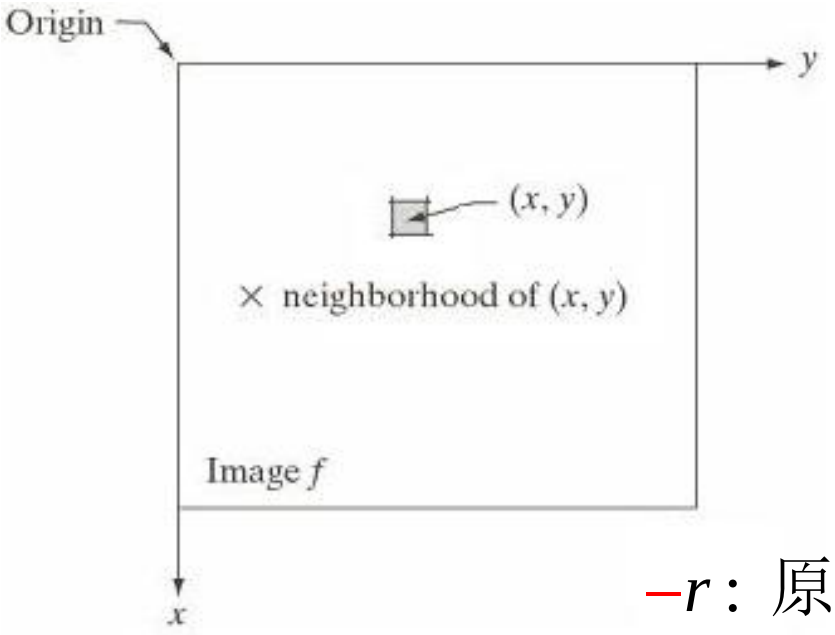
$$g(x,y) = T(f(x,y)) \Rightarrow g = T(f)$$

3. Intensity transformations & spatial filtering

- Background
- Some basic intensity transformation
- Histogram-based image enhancement
- Fundamentals of spatial filtering
- Smoothing spatial filters
- Sharpen spatial filters

3.2 Some basic intensity transformation functions

- **"Basic" comes from the neighbohood size**
  1×1, i.e. a single pixel



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

$$s = T\left[r\right]$$

– r：原图像$f(x,y)$在(x,y)处的灰度值

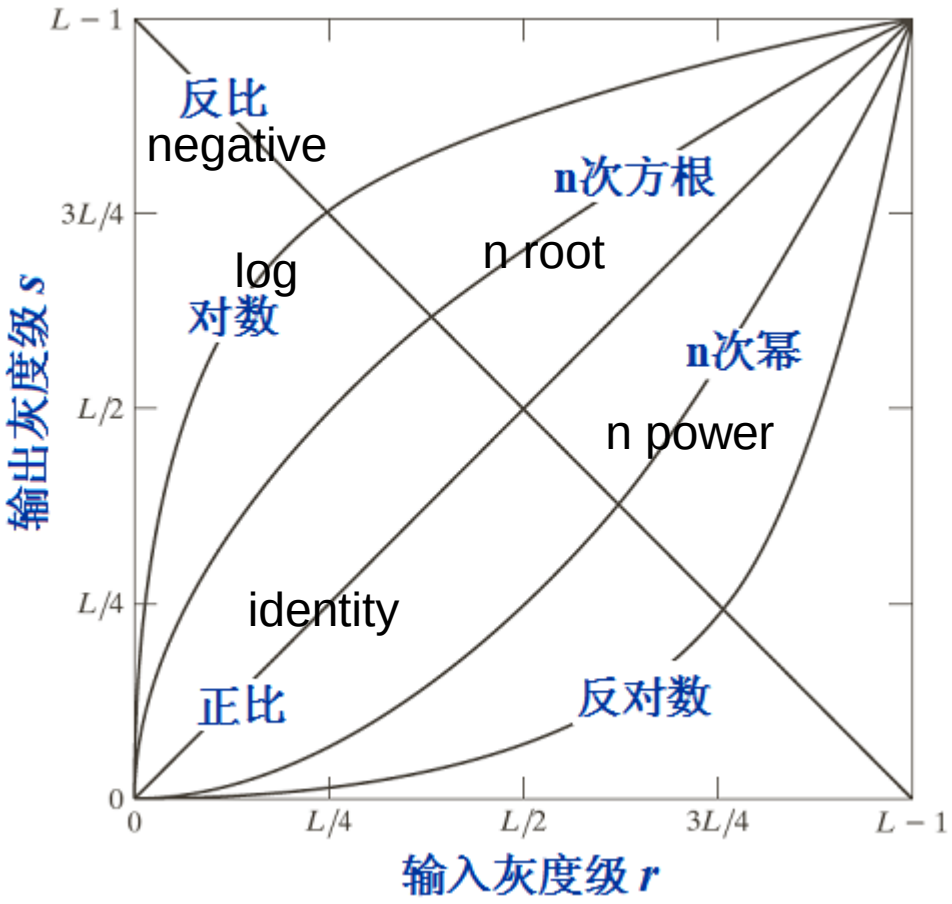
– s：增强图像$g(x,y)$在(x,y)处的灰度值

$T\left[\bullet\right]$：增强算子

Point processing (Basic)

Neighborhood processing

3.2 Some basic intensity transformation functions

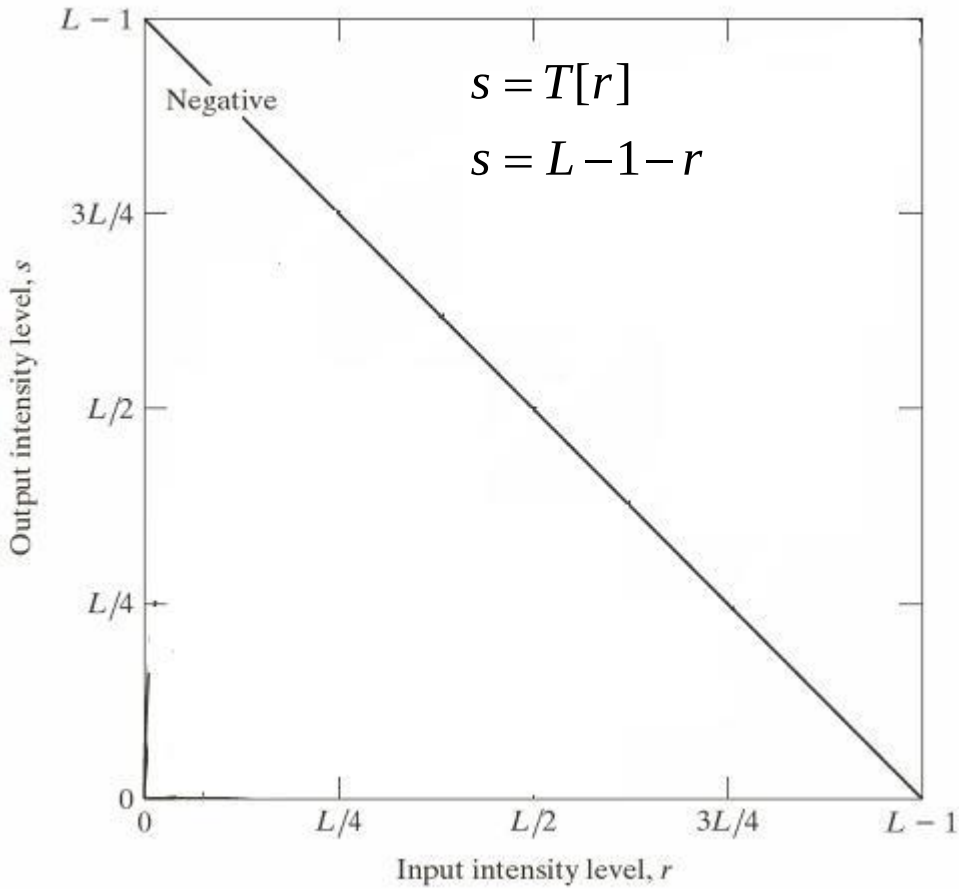


$$s = T[r]$$

- **3类基本灰度变换技术**
  1. **线性: 正比, 反比**
  2. **对数: 对数, 反对数**
  3. **幂次: *n*次幂, *n*次方根**

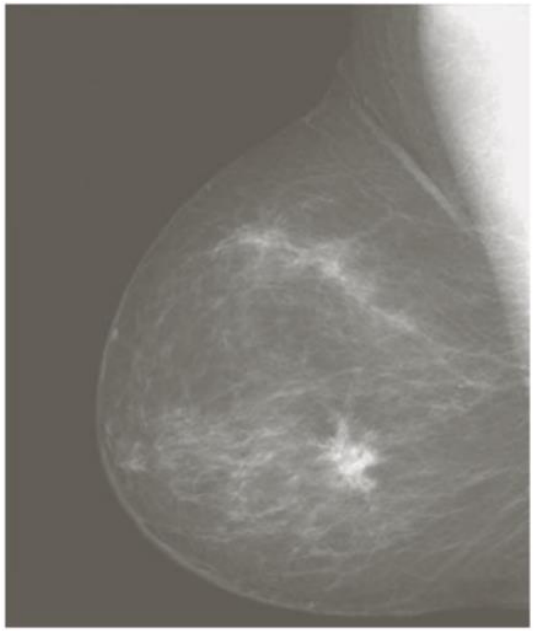
3.2.1 Image negatives

- 输入图像的灰度级r范围[0, L-1],即$0 \le r \le L-1$
- 输出图像的灰度为 $s=L-1-r$
- 灰度图像: “黑白颠倒”
  彩色图像: 补色
- 适用于增强图像中暗色区域的灰色细节部分



It makes all the difference whether one sees darkness through the light or brightness through the shadows

3.2.1 Image negatives



灰度图像

Examples

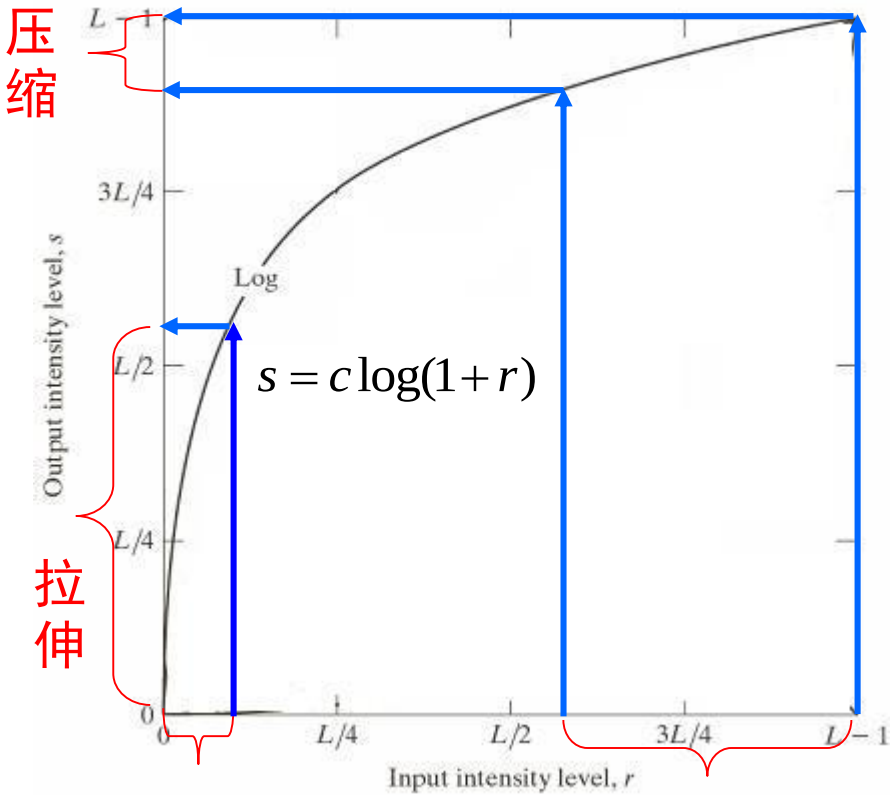
彩色图像

3.2.2 Log transformations

- 对数变换表达式

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

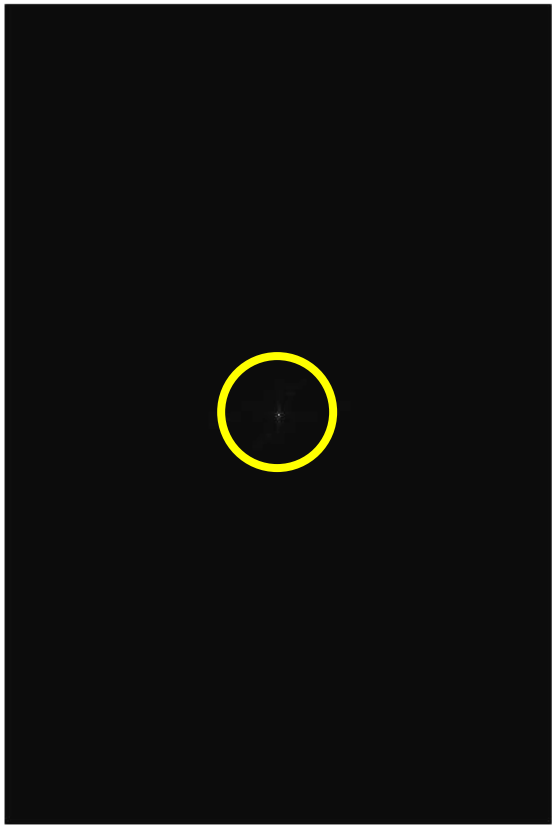
- 把窄范围的低灰度级映射到宽范围的灰度级 (增强低灰度级)
- 把宽范围的高灰度级映射到低范围的灰度级 (抑制高灰度级)
- 应用: 压缩图像的动态范围, 显示图像的傅里叶频谱图像



3.2.2 Log Transformation

➢示例: 利用对数变换显示图像的傅里叶频谱

图像



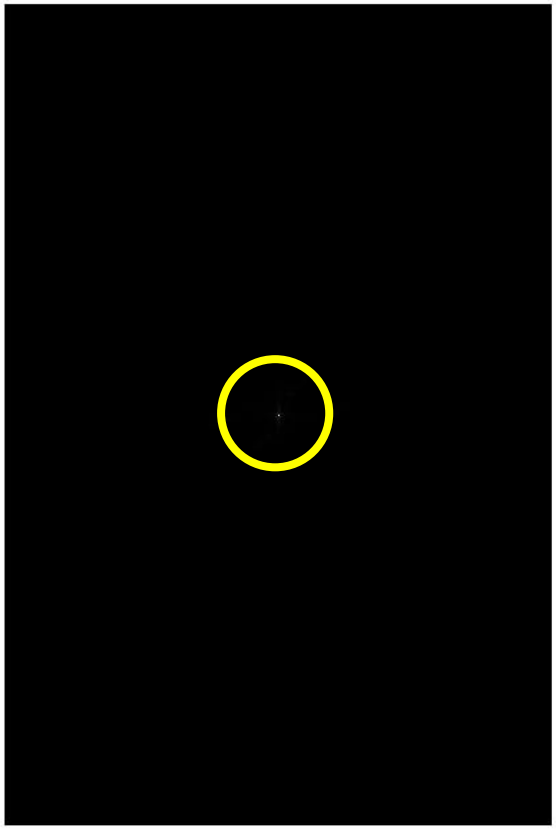
图像的傅里叶谱

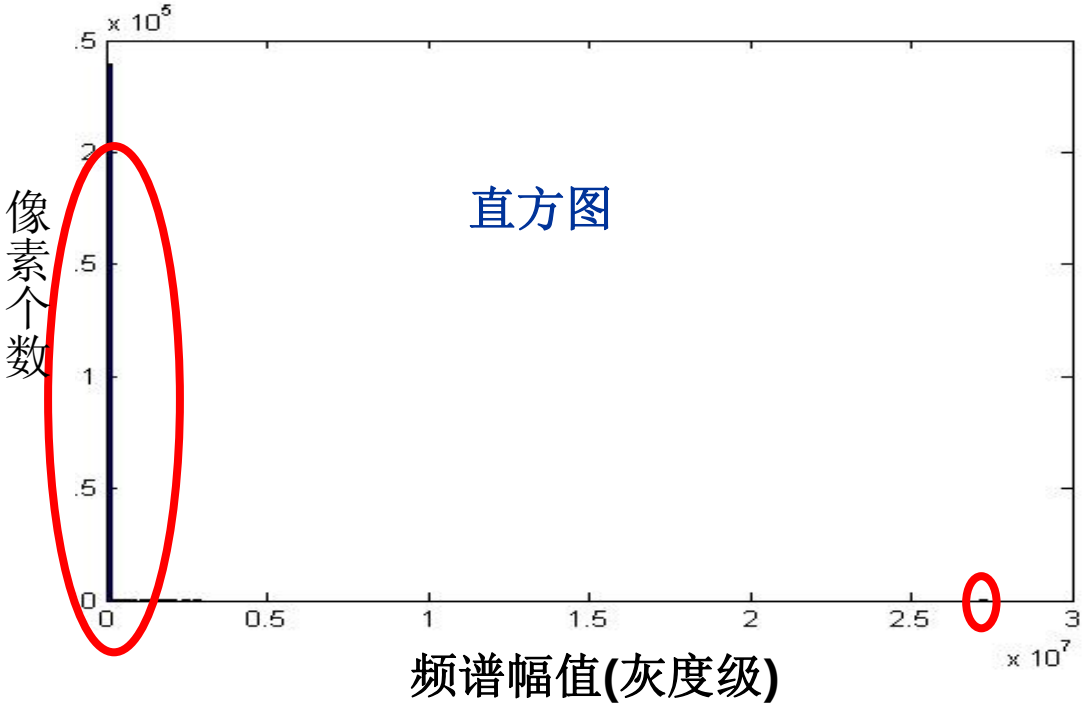
频谱幅值范围:0~10^7,
且低频能量最多

3.2.2 Log transformations

- 图像傅里叶谱的直方图

$r \in [0, 1.5\times10^6]$

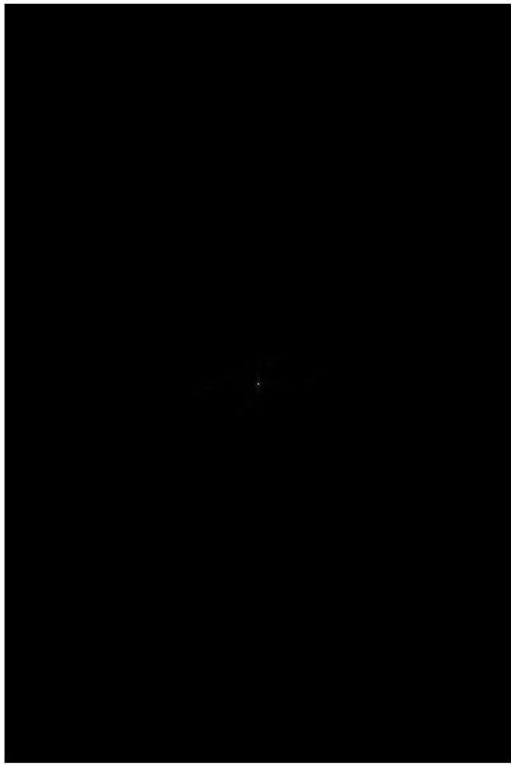




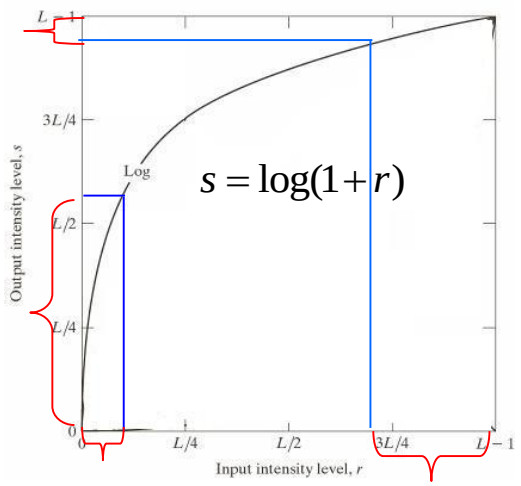
3.2.2 Log transformations

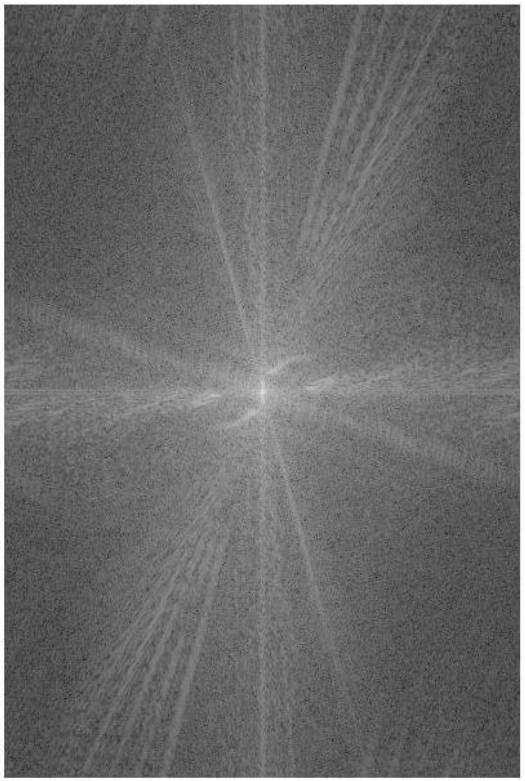
- 对数变换的应用: 频谱显示

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



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



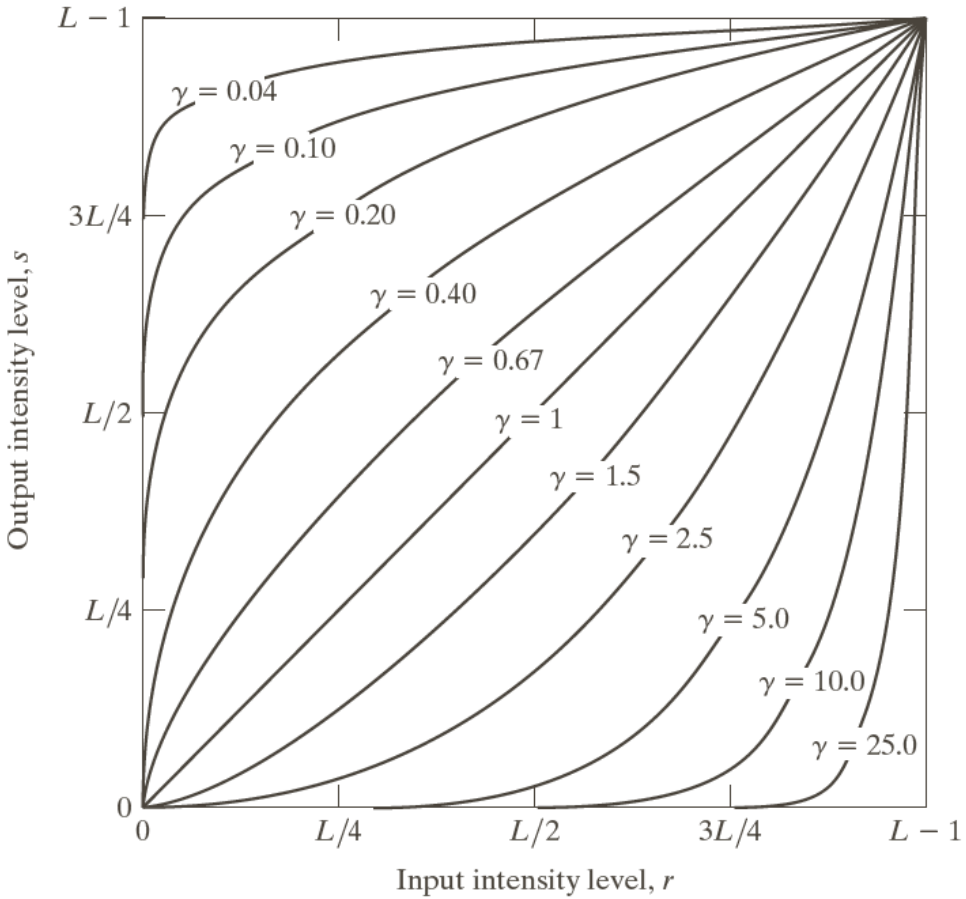


3.2.3 Power-law (Gamma) transformation

- 幂次变换表达式

  $s = cr^{\gamma}$

- γ<1: 扩展暗像素值, 压缩亮像素值
- γ>1: 压缩暗像素值, 扩展亮像素值
- 应用: 用于各种图像获取、打印和显示等设备的伽马校正 **(Gamma correction)**



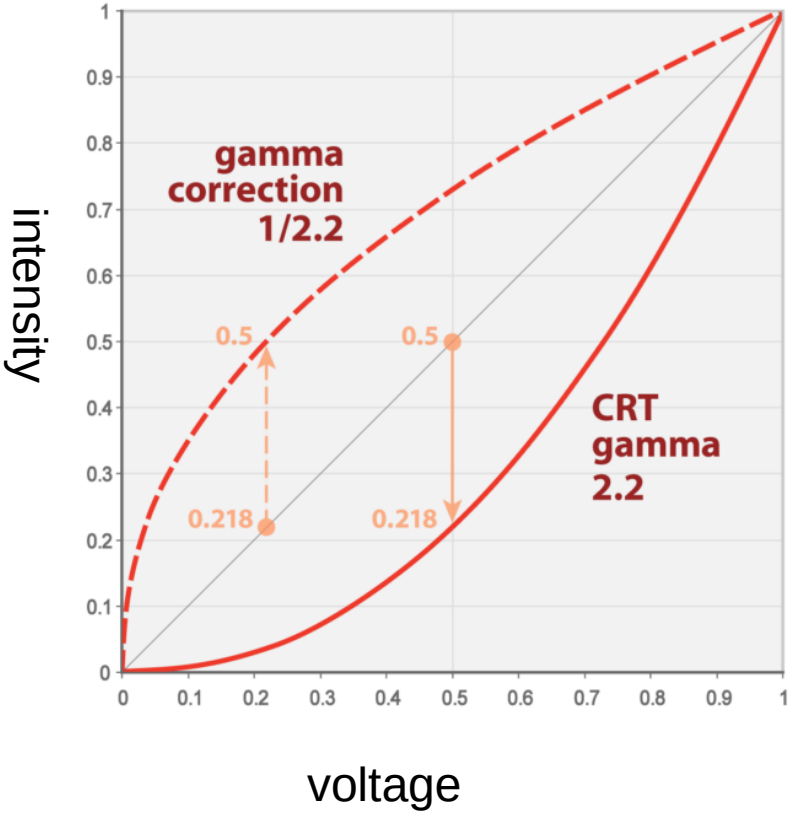
3.2.3 Power-law (Gamma transformation

- **CRT**(阴极射线管)设备的电压-亮度曲线近似为幂函数

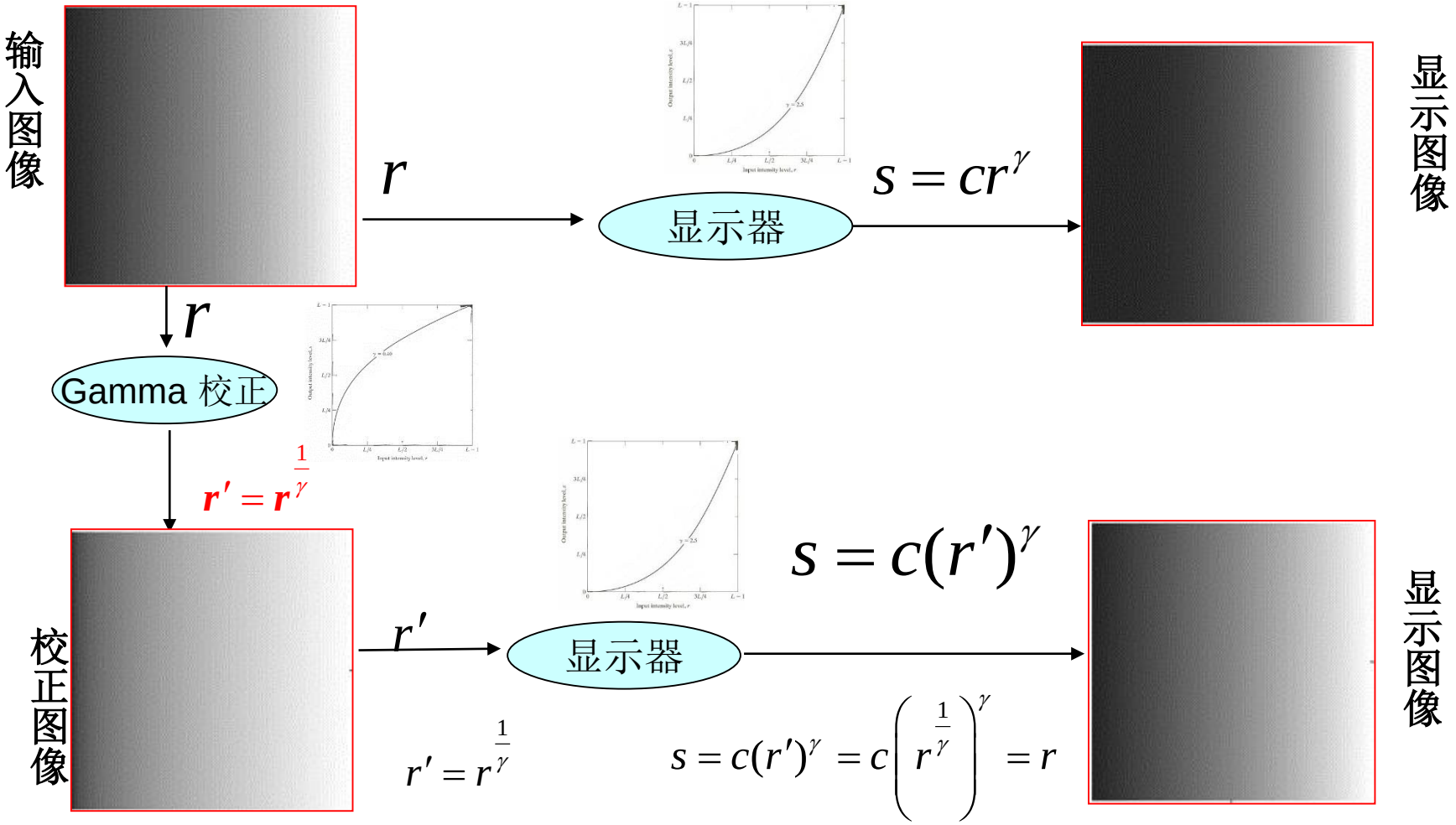
$$s = r^{\gamma}, \quad \gamma = 1.8 \sim 2.5$$

- 没有进行伽马校正的输出图像比输入图像暗,且暗区被压缩
- 将经过伽马校正后的图像r'作为输入, 得到接近真实的显示效果

$$s = (r')^{\gamma} = r^{\frac{1}{\gamma} \times \gamma} = r$$



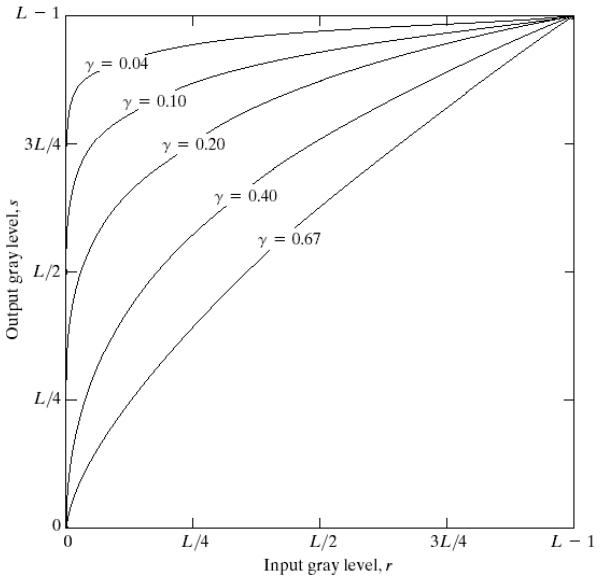
3.2.3 Power-law (Gamma) transformation



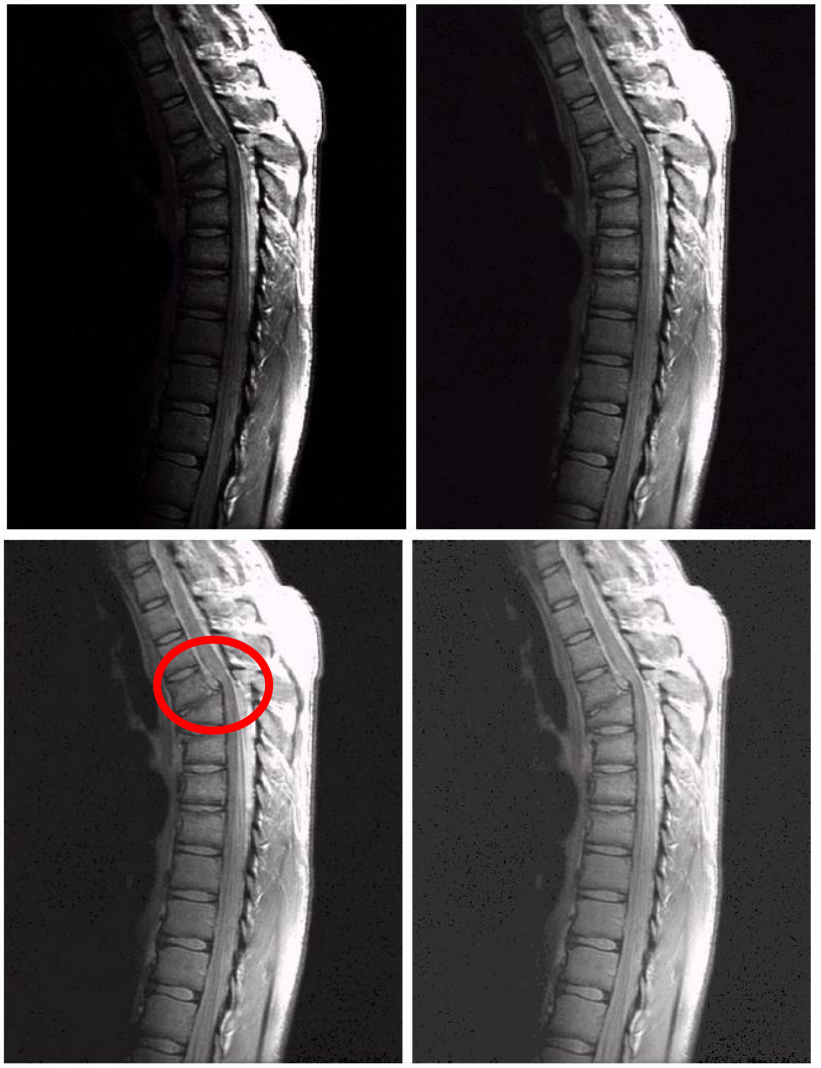
3.2.3 Power-law (Gamma) transformation

➢扩展暗灰度级：
MR图像增强

原始图像



$\gamma = 0.4$

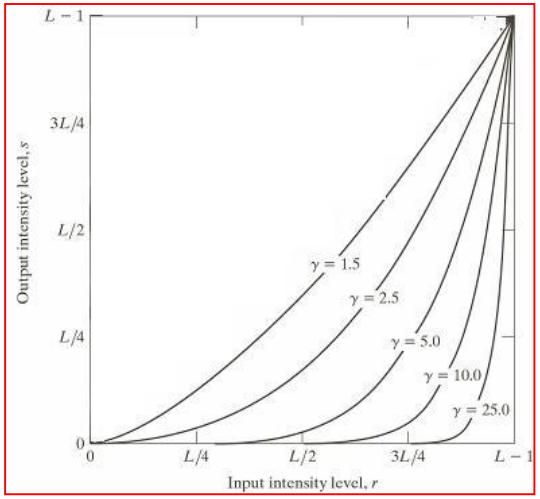


$\gamma = 0.6$

$\gamma = 0.3$

3.2.3 Power-law (Gamma) transformation

- 压缩亮灰度级：航拍图像增强



原始航拍图像(washed out)

$\gamma = 3$

$\gamma = 4$

$\gamma = 5$

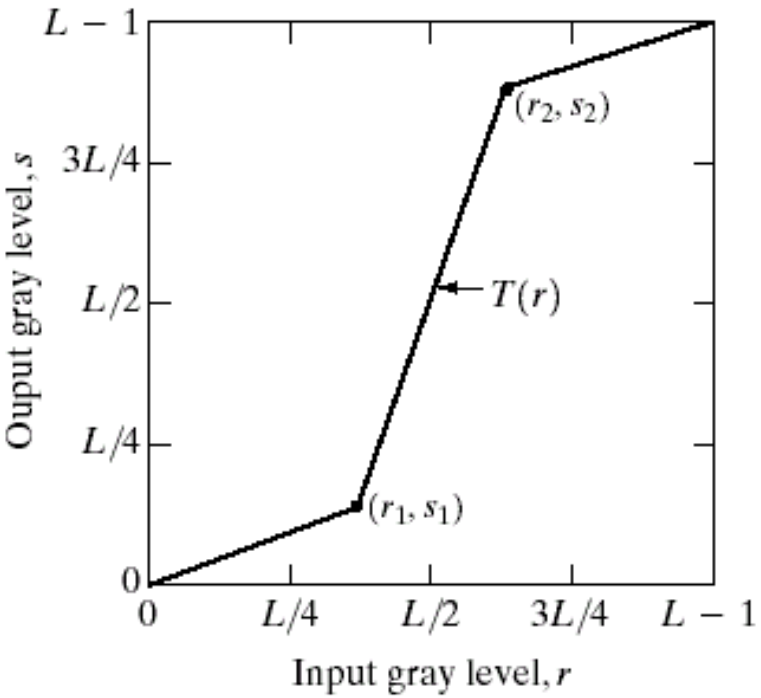
3.2.4 Piecewise-linear transformation functions

- 分段线性变换: 将灰度级划归不同范围, 每个范围采用不同的线性变换
- 优点: 变换形式可根据需要任意合成
- 缺点: 需用户输入
- 主要形式:
  - 对比度拉伸
  - 灰度切割
  - 位图切割（自学）

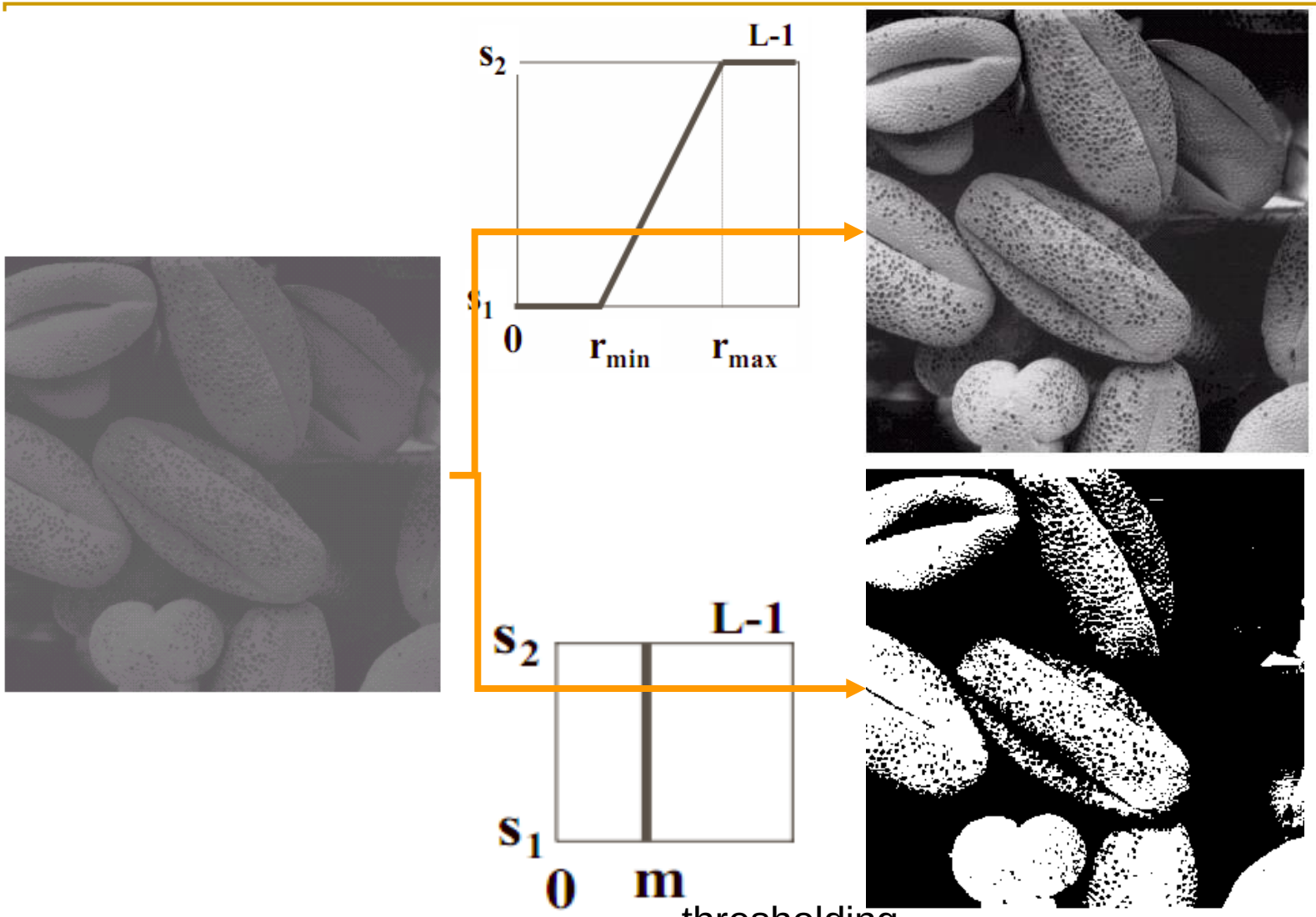
3.2.4 Piecewise-linear transformation functions

- 对比度拉伸: 提高图像灰度级的动态范围

$$s = T(r) = \begin{cases} a_1 r & 0 \le r < r_1 \\ a_2(r - r_1) + s_1 & r_1 \le r < r_2 \\ a_3(r - r_2) + s_2 & r_2 \le r \le L-1 \end{cases}$$

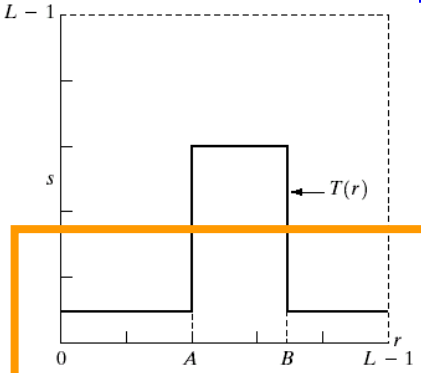


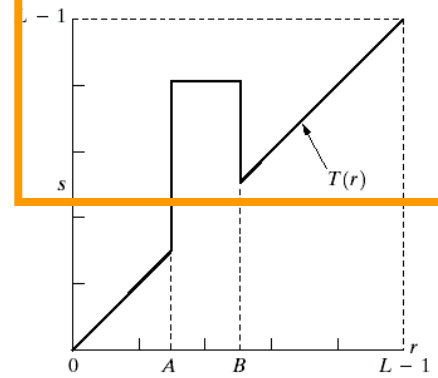
3.2.4 Piecewise-linear transformation functions



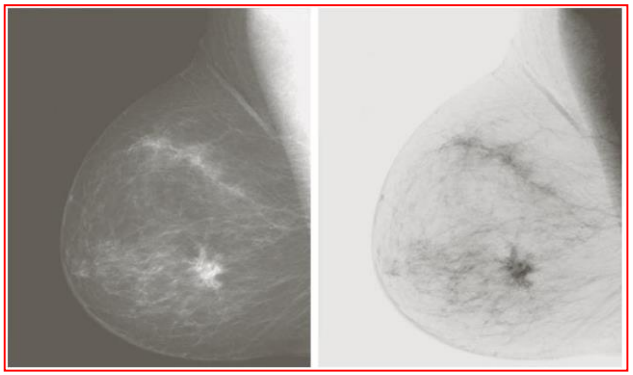
thresholding

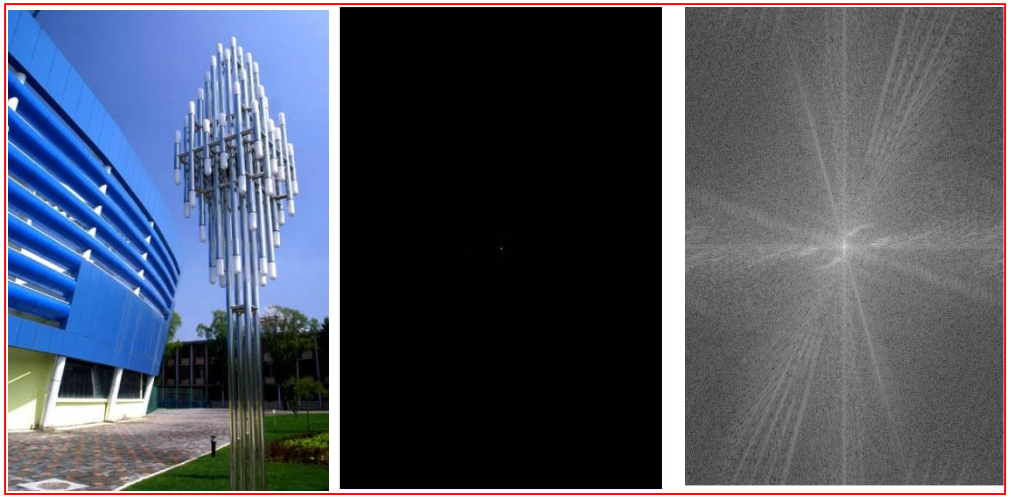
3.2.4 Piecewise-linear transformation functions

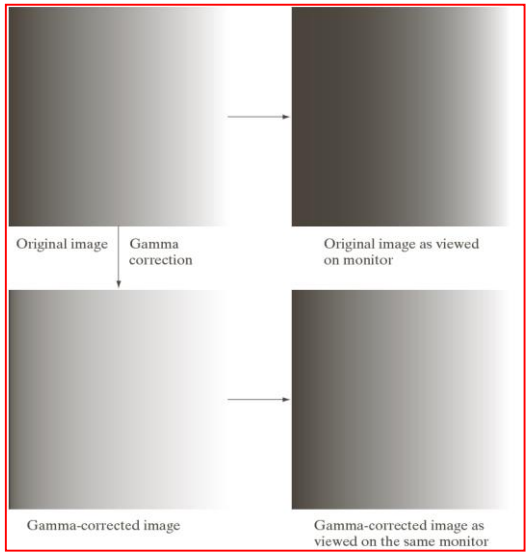


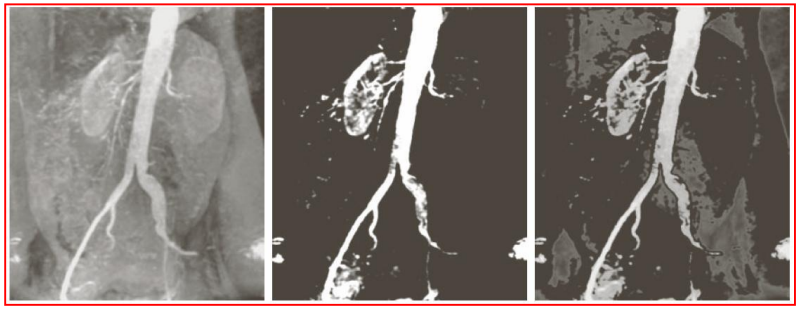


Summary of basic intensity transform









What are changed by intensity transform

What ‘s the drawback? (not automatic)