Ψηφιακή Επεξεργασία Εικόνας (ΨΕΕ) – MYE037

Εαρινό εξάμηνο 2023-2024

Intensity Transformations (Point Processing)

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Images taken from:
R. Gonzalez and R. Woods. Digital Image Processing, Prentice Hall, 2008.
Digital Image Processing course by Brian Mac Namee, Dublin Institute of Technology.

Intensity Transformations

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

David Lindsay
(Scottish Novelist)

Contents

Over the next few lectures we will look at image enhancement techniques working in the spatial domain:

- What is image enhancement?
- Different kinds of image enhancement
- Point processing
- Histogram processing
- Spatial filtering

What Is Image Enhancement?

Image enhancement is the process of making images more useful

The reasons for doing this include:

- Highlighting interesting detail in images
- Removing noise from images
- Making images more visually appealing

Image Enhancement Examples

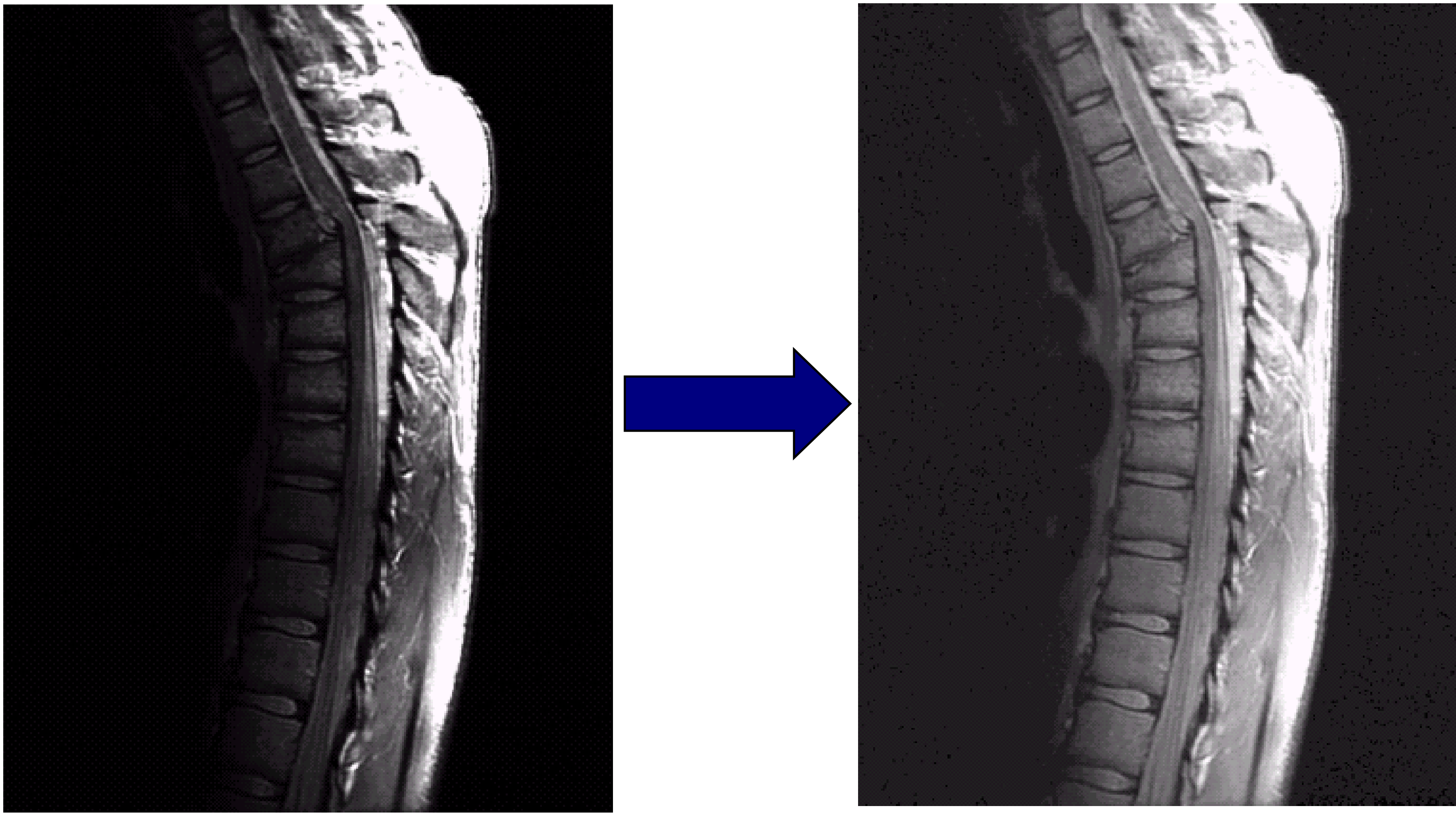

Image Enhancement Examples (cont…)

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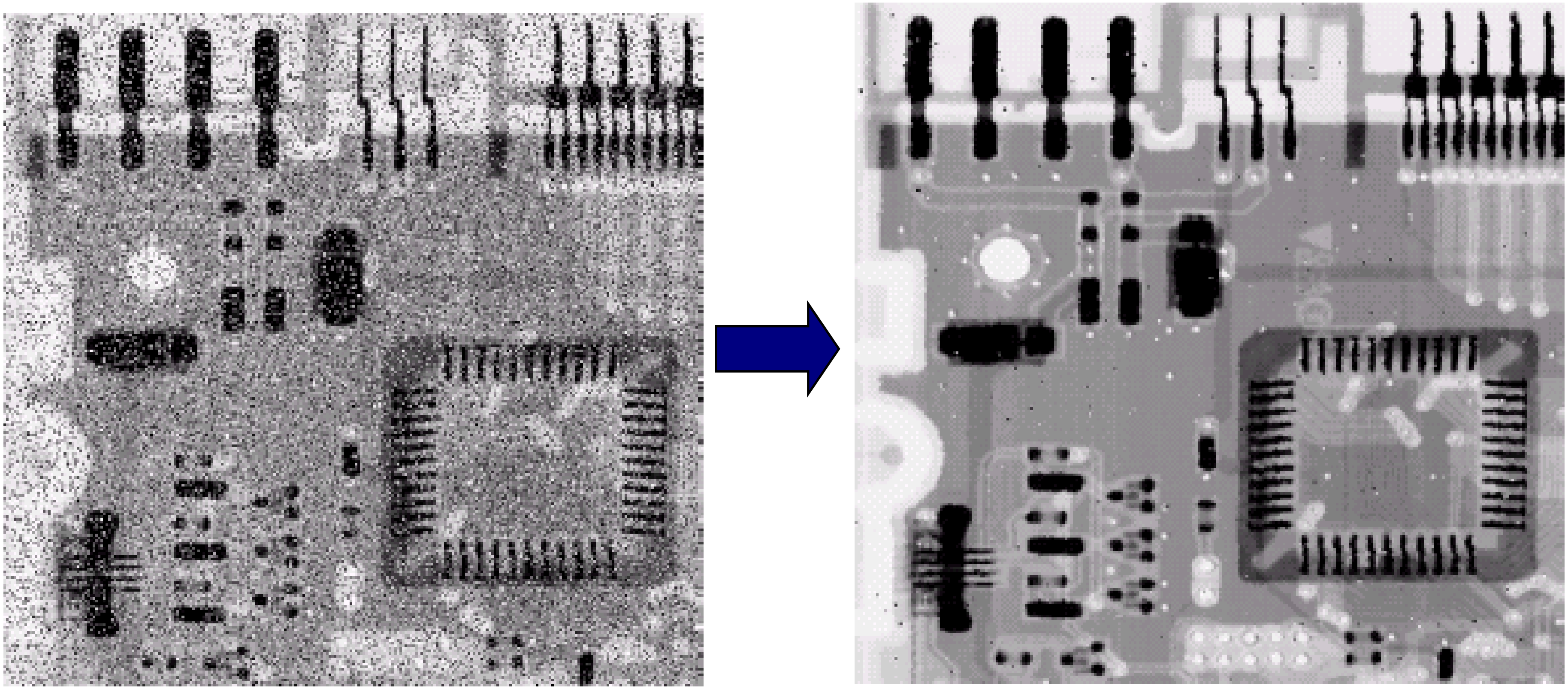


Image Enhancement Examples (cont…)

Spatial & Frequency Domains

There are two broad categories of image enhancement techniques

- **Spatial domain techniques**
  - Direct manipulation of image pixels
- Frequency domain techniques
  - Manipulation of Fourier transform or wavelet transform of an image

For the moment we will concentrate on techniques that operate in the spatial domain

Contents

In this lecture we will look at image enhancement point processing techniques:

- What is point processing?
- Negative images (highlighting)
- Thresholding (e.g., binary image)
- Logarithmic transformation (low intensity)
- Power law transforms (brightness/contrast)
- Grey level slicing (linear, log, power)
- Bit plane slicing (compression)

A Note About Grey Levels

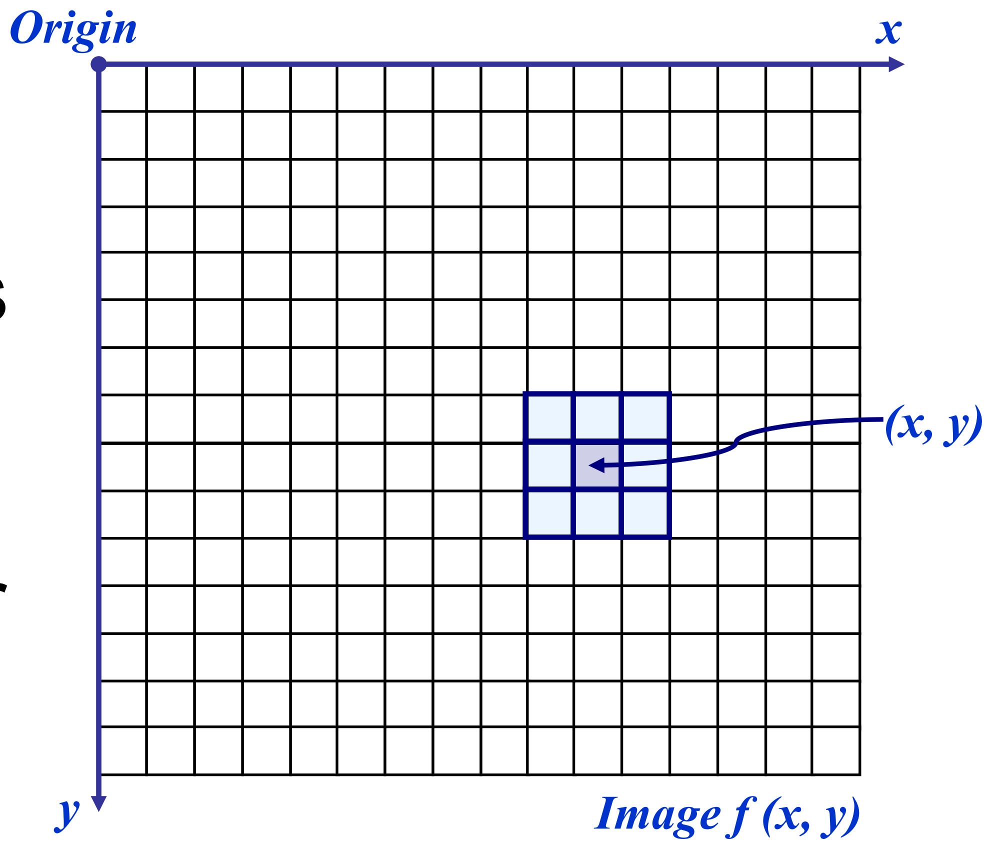
- So far when we have spoken about image grey level values we have said they are in the range [0, 255]
  - Where 0 is black and 255 is white
- There is no reason why we have to use this range
  - The range [0,255] stems from display technologies
- For many of the image processing operations in this lecture grey levels are assumed to be given in the range [0.0, 1.0]

Basic Spatial Domain Image Enhancement

Most spatial domain enhancement operations can be reduced to the form

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

where $f(x, y)$ is the input image, $g(x, y)$ is the processed image and T is some operator defined over some neighbourhood of (x, y)



Point Processing

The simplest spatial domain operations occur when the neighbourhood is simply the pixel itself

In this case T is referred to as a *grey level transformation function* or a *point processing operation*

Point processing operations take the form

$$s = T(r)$$

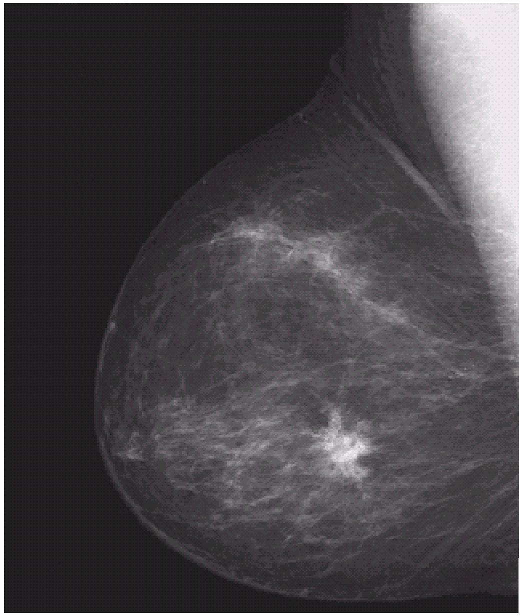
where s refers to the processed image pixel value and r refers to the original image pixel value.

Point Processing Example: Negative Images

Negative images are useful for enhancing white or grey detail embedded in dark regions of an image

- Note how much clearer the tissue is in the negative image of the mammogram below

Original Image



$s = 1.0 - r$

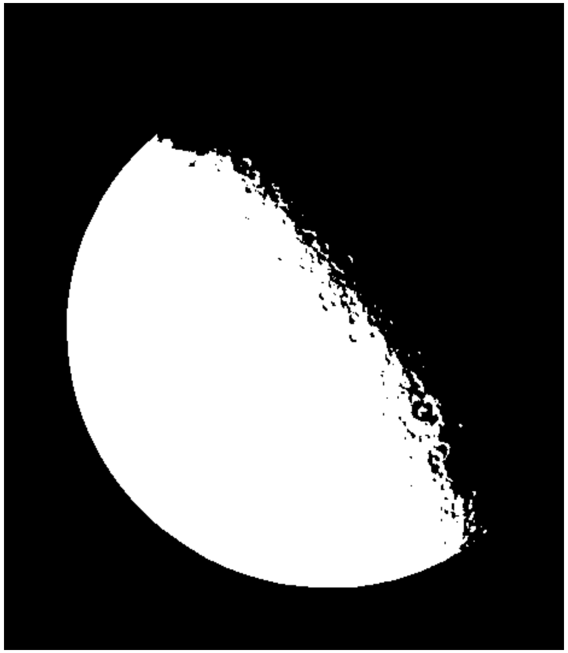
Negative Image

(MYE037)

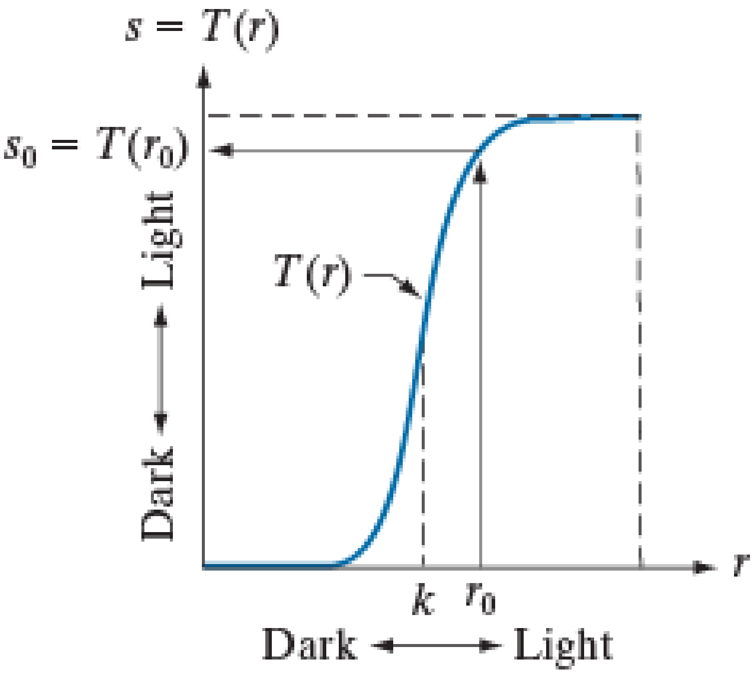
Point Processing Example: Thresholding

Thresholding transformations are particularly useful for segmentation in which we want to isolate an object of interest from a background

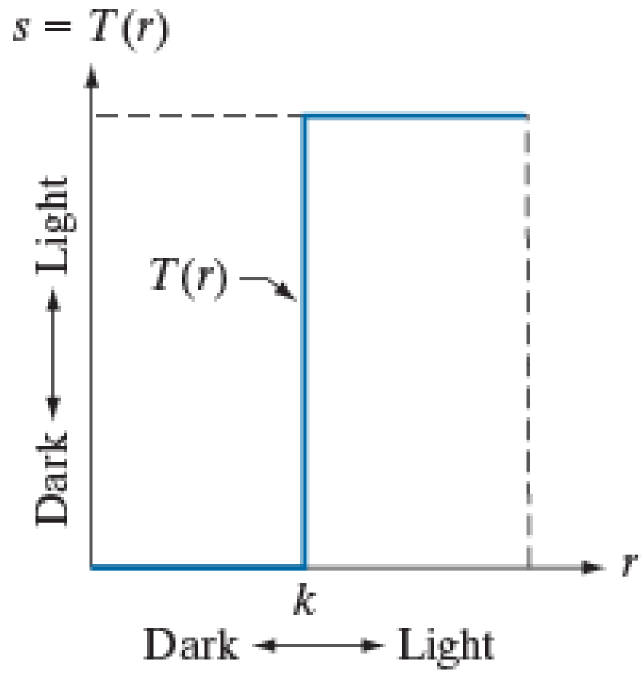
$$s = \begin{cases} 1.0 & r > \text{threshold} \\ 0.0 & r <= \text{threshold} \end{cases}$$



Intensity Transformations



Contrast stretching



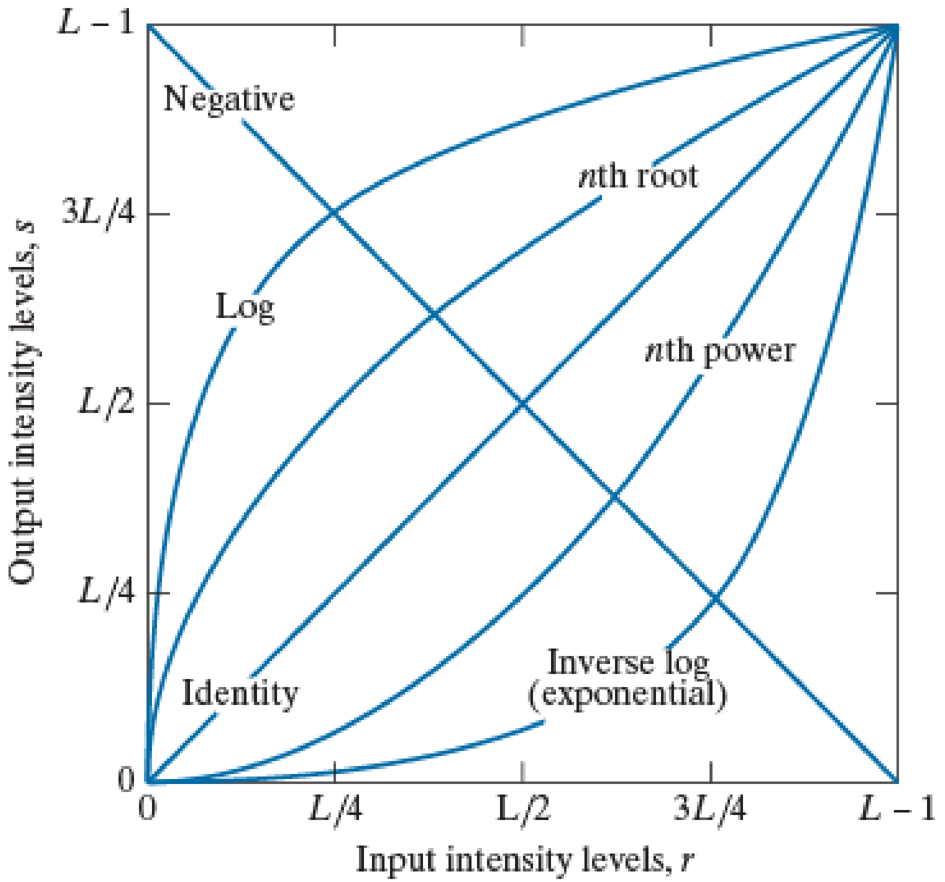
Thresholding

Basic Grey Level Transformations

There are many different kinds of grey level transformations

Three of the most common are shown here

- Linear
  - Negative/Identity
- Logarithmic
  - Log/Inverse log
- Power law
  - n^{th} power/n^{th} root



Logarithmic Transformations

The general form of the log transformation is

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

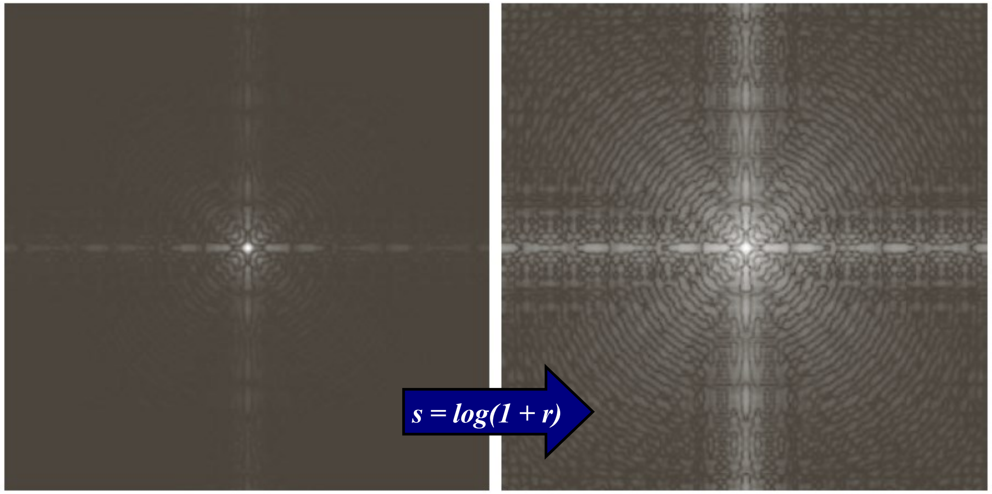
The log transformation maps a narrow range of low input grey level values into a wider range of output values

The inverse log transformation performs the opposite transformation

Logarithmic Transformations (cont…)

Log functions are particularly useful when the input grey level values may have an extremely large range of values

In the following example the Fourier transform of an image is put through a log transform to reveal more detail



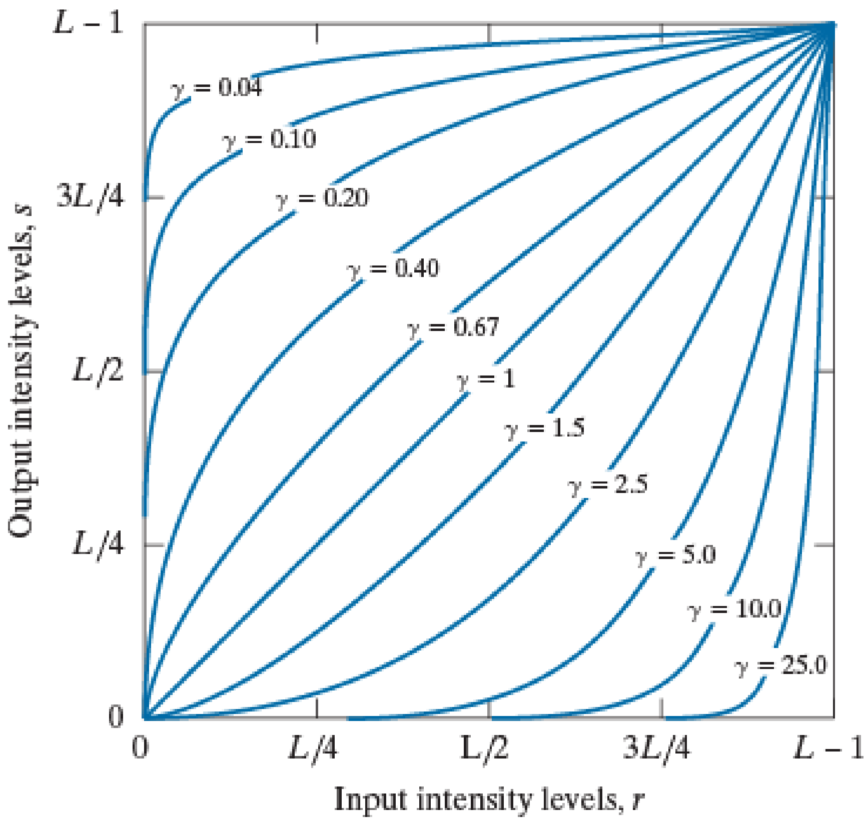
Power Law Transformations

Power law transformations have the following form

$$s = c * r^{\gamma}$$

Map a narrow range of dark input values into a wider range of output values or vice versa

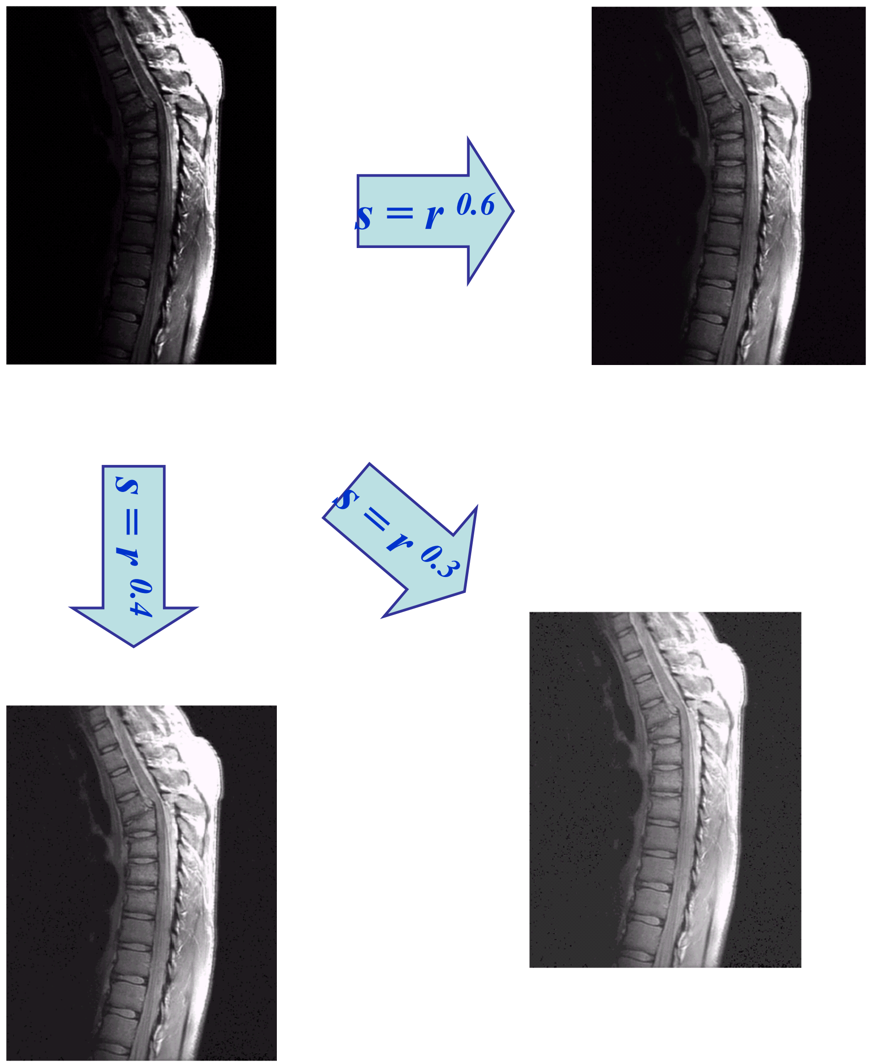
Varying γ gives a whole family of curves



Power Law Example (cont…)

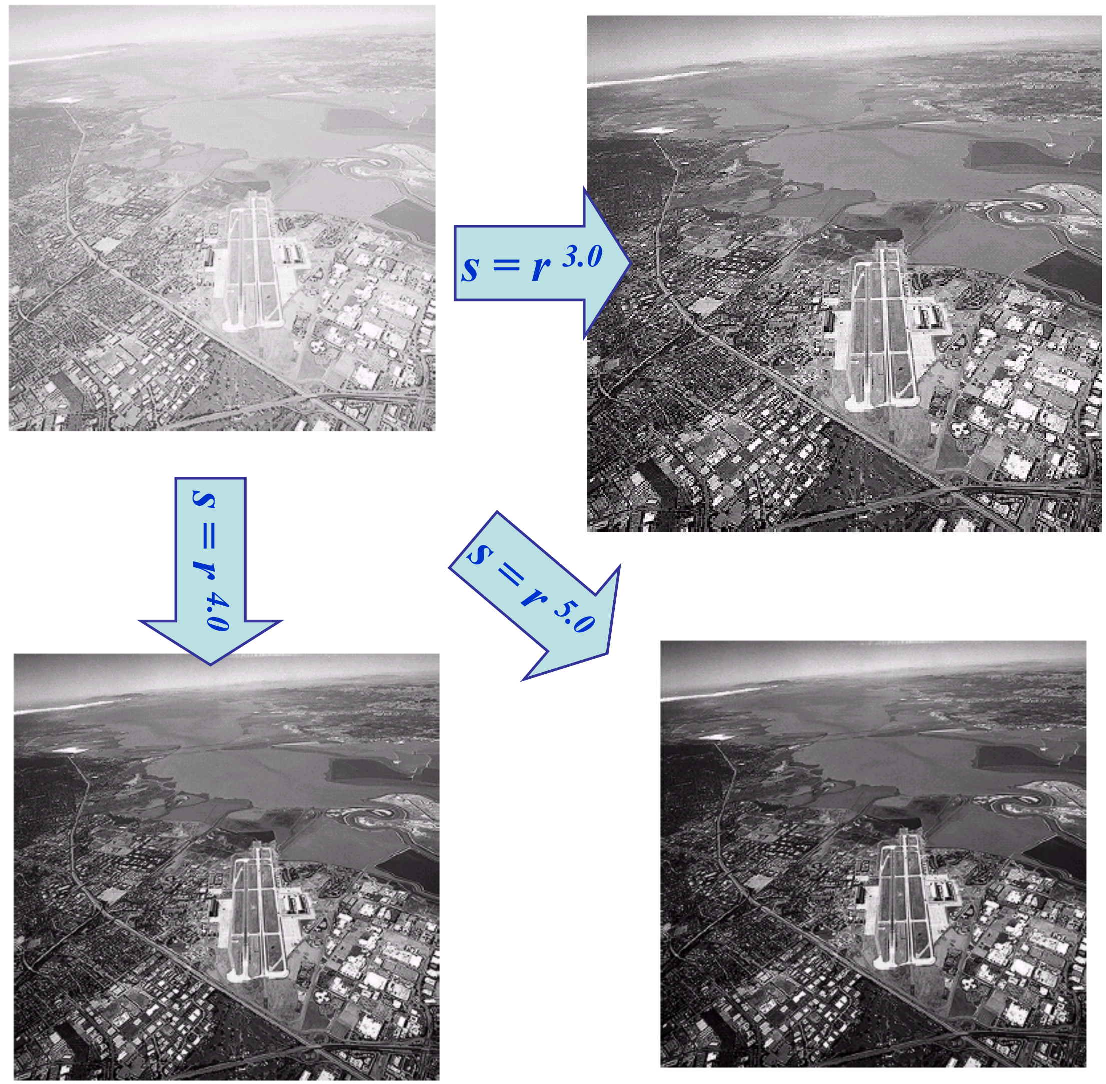
The images to the right show a magnetic resonance (MR) image of a fractured human spine

Different curves highlight different detail



Power Law Transformations (cont…)

- An aerial photo of a runway is shown
- This time power law transforms are used to darken the image
- Different curves highlight different detail

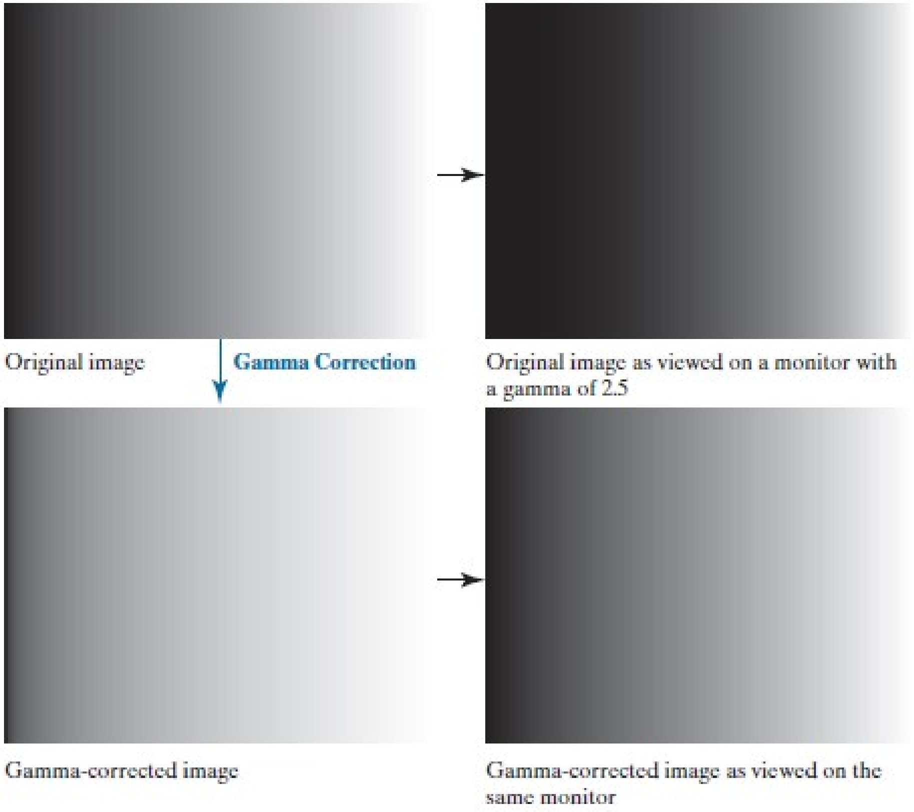


Gamma Correction

Many of you might be familiar with gamma correction of computer monitors

Problem is that display devices do not respond linearly to different intensities

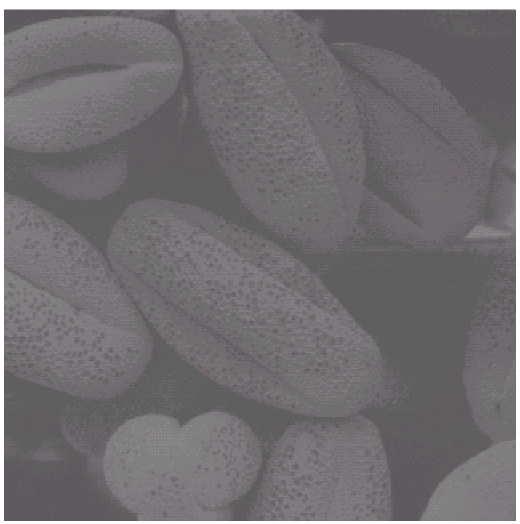
Can be corrected using a log transform

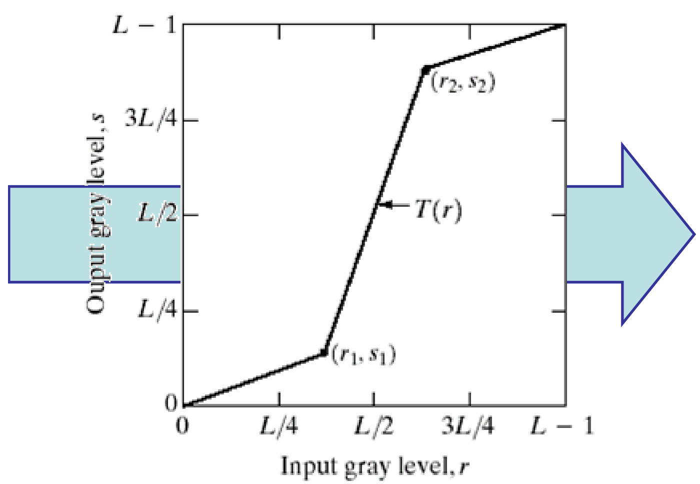


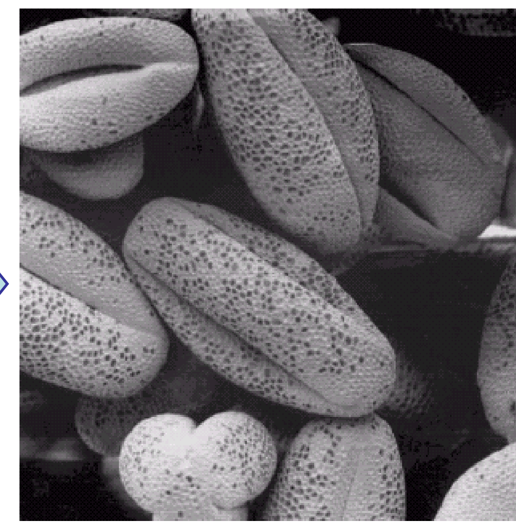
Piecewise Linear Transformation Functions

Rather than using a well defined mathematical function we can use arbitrary user-defined transforms

The images below show a contrast stretching linear transform to add contrast to a poor quality image

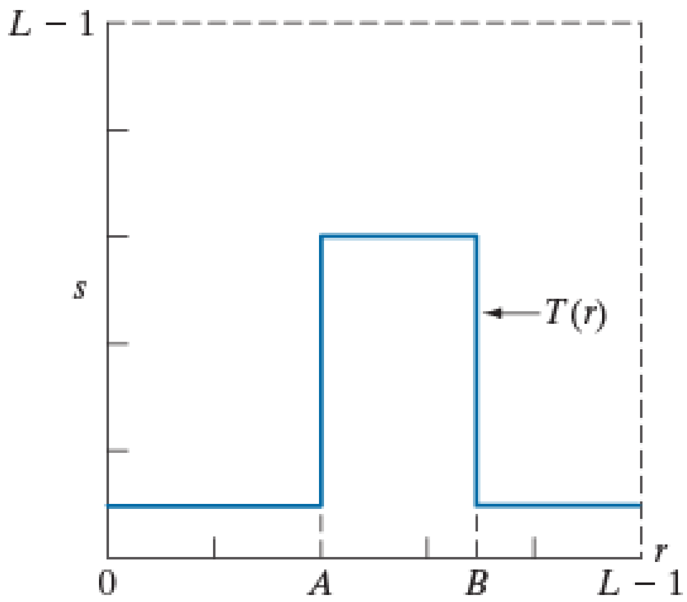


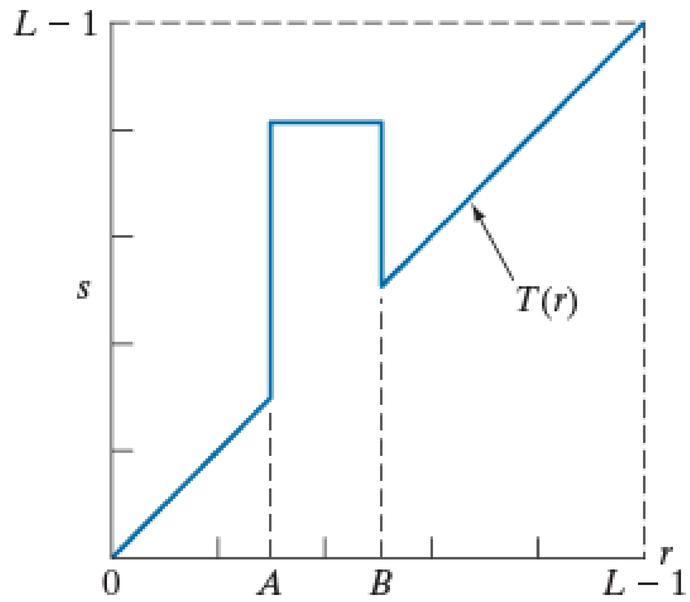




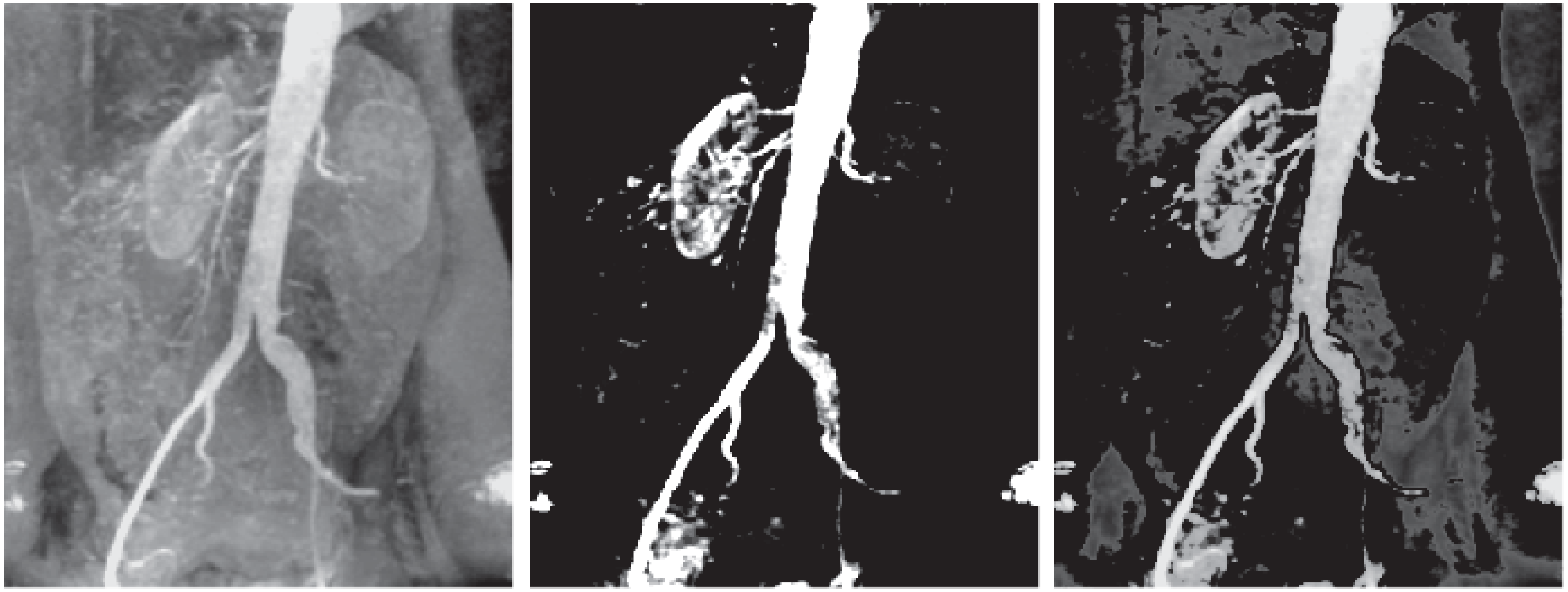
Piecewise-Linear Transformation (cont…)

(a) This transformation function highlights range [A,B] and reduces all other intensities to a lower level.
(b) This function highlights range [A,B] and leaves other intensities unchanged.





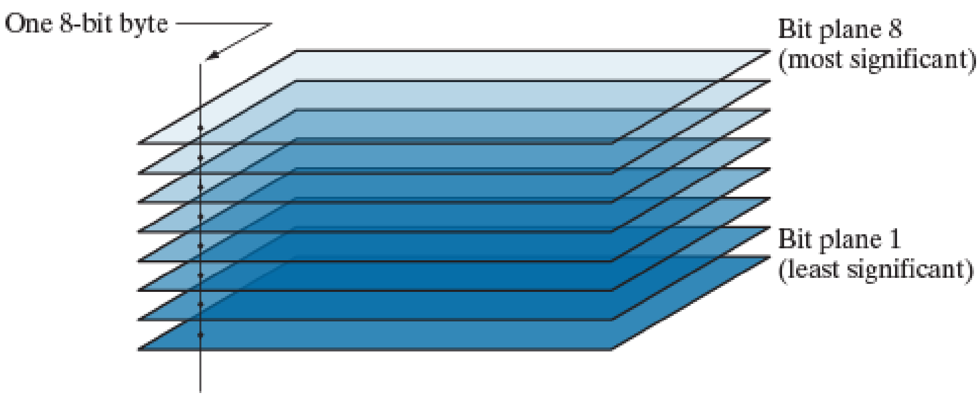
Piecewise-Linear Transformation (cont…)



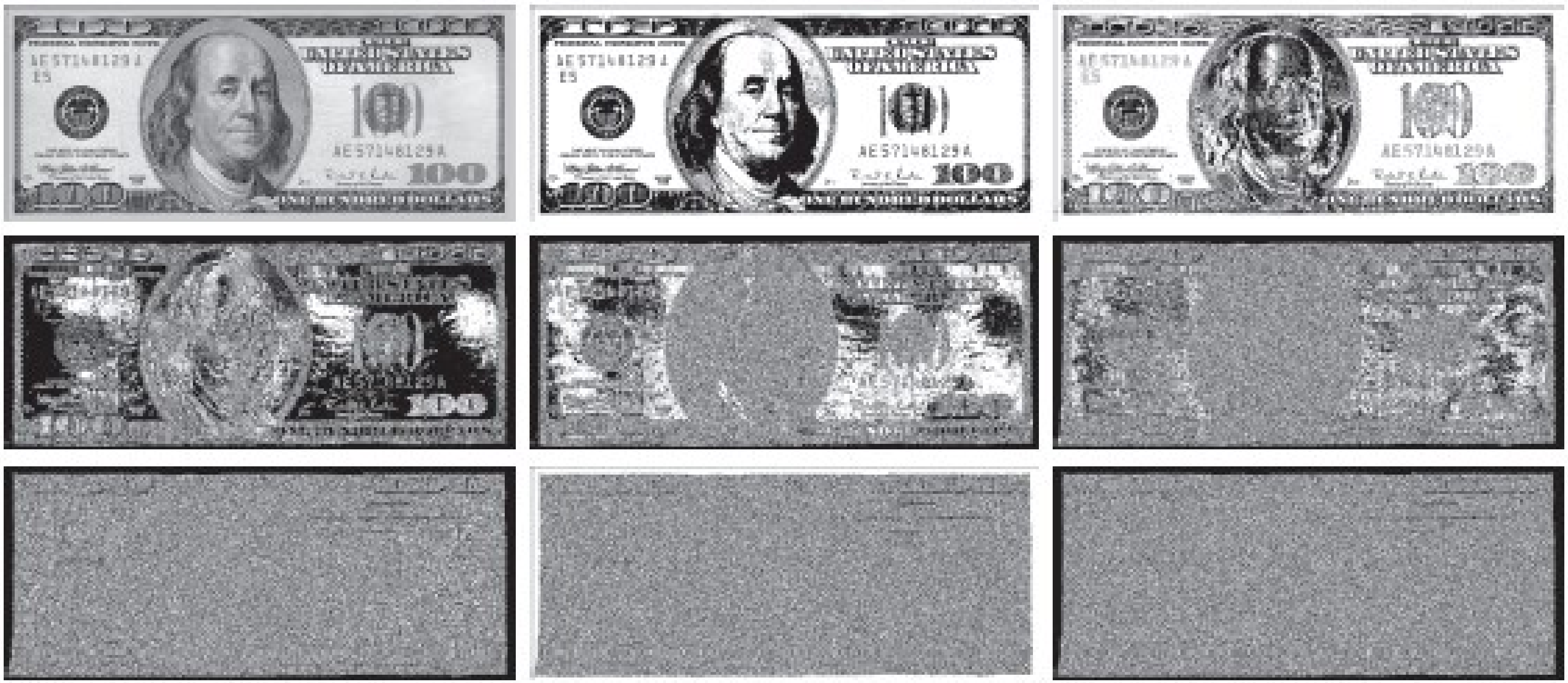
Bit Plane Slicing

Often by isolating particular bits of the pixel values in an image we can highlight interesting aspects of that image

- Higher-order bits usually contain most of the significant visual information
- Lower-order bits contain subtle details



Bit-Plane Slicing (cont…)



Bit-Plane Slicing (cont…)

a b c FIGURE 3.15 Image reconstructed from bit planes: (a) 8 and 7; (b) 8, 7, and 6; (c) 8, 7, 6, and 5.

Useful for compression.

Reconstruction is obtained by:

$$I(i,j)=\sum_{n=1}^{N}2^{n-1}I_n(i,j)$$

Average image

Let $g(x,y)$ denote a corrupted image by adding noise $\eta(x,y)$ to a noiseless image $f(x,y)$:

$$g(x, y) = f(x, y) + \eta(x, y)$$

The noise has zero mean value $E[z_i] = 0$

At every pair of coordinates $z_i=(x_i,y_i)$ the noise is uncorrelated

$$E[z_i z_j] = 0, \; E[z_i^2] = \sigma_\eta^2$$

Average image (cont...)

The noise effect is reduced by averaging a set of K noisy images. The new image is

$$\overline{g}(x,y)=\frac{1}{K}\sum_{i=1}^{K}g_i(x,y)$$

The intensities at each pixel of the new image may be viewed as random variables.

The mean value and the standard deviation of the new image show that the effect of noise is reduced.

Average image (cont...)

$$E\left[\bar{g}(x,y)\right] = E\left[\frac{1}{K}\sum_{i=1}^{K} g_i(x,y)\right] = \frac{1}{K} E\left[\sum_{i=1}^{K} g_i(x,y)\right]$$

$$= \frac{1}{K} E\left[\sum_{i=1}^{K} f(x,y) + \eta_i(x,y)\right]$$

$$= \frac{1}{K} E\left[\sum_{i=1}^{K} f(x,y)\right] + \frac{1}{K} E\left[\sum_{i=1}^{K} \eta_i(x,y)\right]$$

$$= \frac{1}{K} K f(x,y) + \frac{1}{K} K 0 \;\; = f(x,y)$$

Average image (cont...)

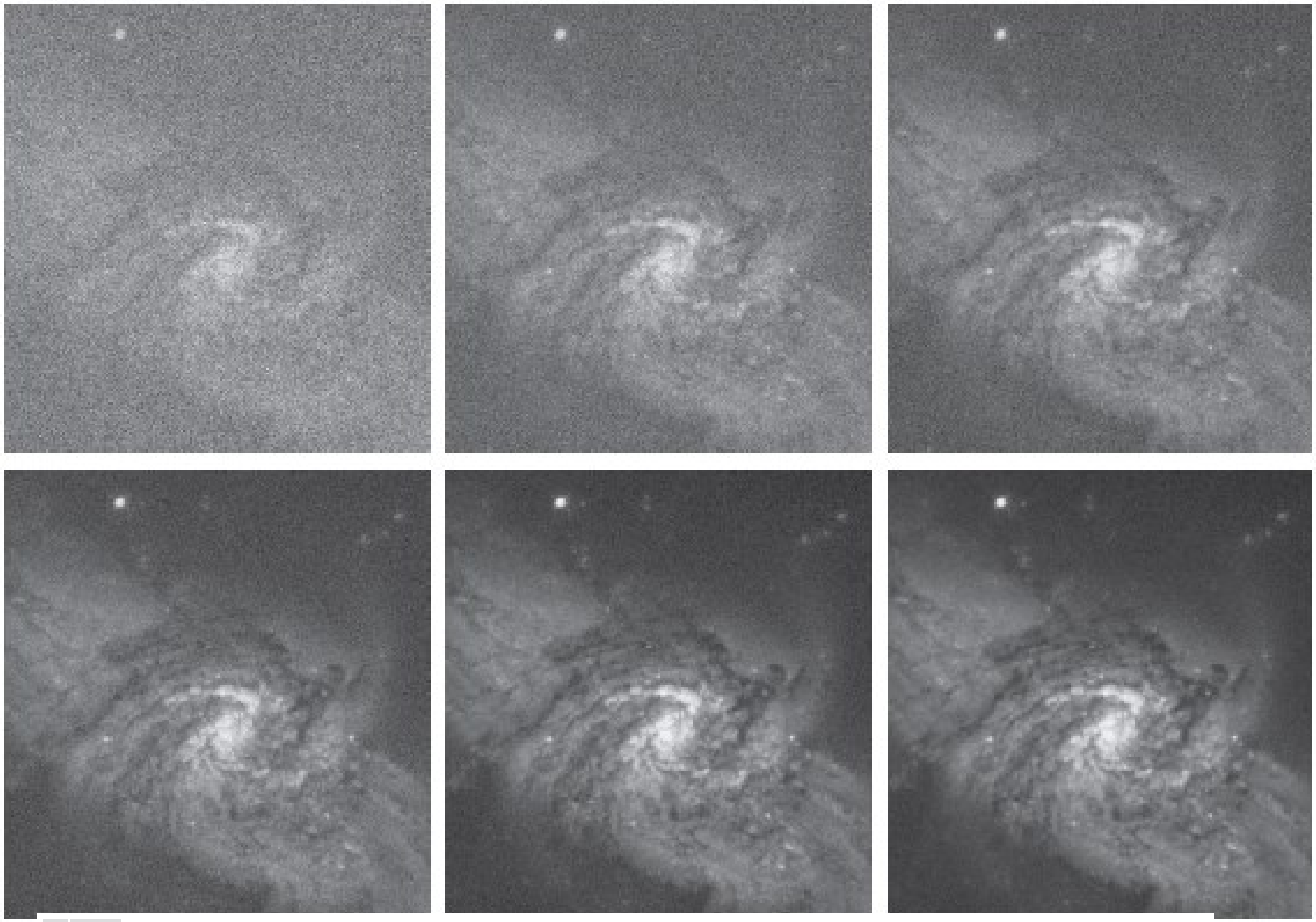
Similarly, the standard deviation of the new image is

$$\sigma_{\bar{g}(x,y)} = E\left[\left(\bar{g}(x,y)\right)^2\right] - \left(E\left[\bar{g}(x,y)\right]\right)^2 = \frac{1}{\sqrt{K}}\sigma_{\eta(x,y)}$$

As K increases the variability of the pixel intensity decreases and remains close to the noiseless image values $f(x,y)$.

The images must be registered!

Average image (cont...)



a b c
d e f

FIGURE 2.29 (a) Image of Galaxy Pair NGC 3314 corrupted by additive Gaussian noise. (b)-(f) Result of averaging 5, 10, 20, 50, and 1,00 noisy images, respectively. All images are of size 566×598 pixels, and all were scaled so that their intensities would span the full [0, 255] intensity scale. (Original image courtesy of NASA.)

Summary

We have looked at different kinds of point processing image enhancement

Next time we will start to look at histogram processing methods.