Review

Last class we have looked at some basic Image Operations.

Q. Image subtraction is used often in industrial applications for detecting missing components in a product assembly. The approach is to store a "golden" image that corresponds to a correct assembly. This image is then subtracted from incoming images of the same product. Ideally, the differences would be zero if the new products are assembled correctly. Difference images for products with missing components would be nonzero in the regions where they differ from the golden image, **What conditions do you think have to be met in practice for this method to work?**

Image Enhancement Methods

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

Spatial domain Image Enhancement

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
- Neighbourhood operations

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

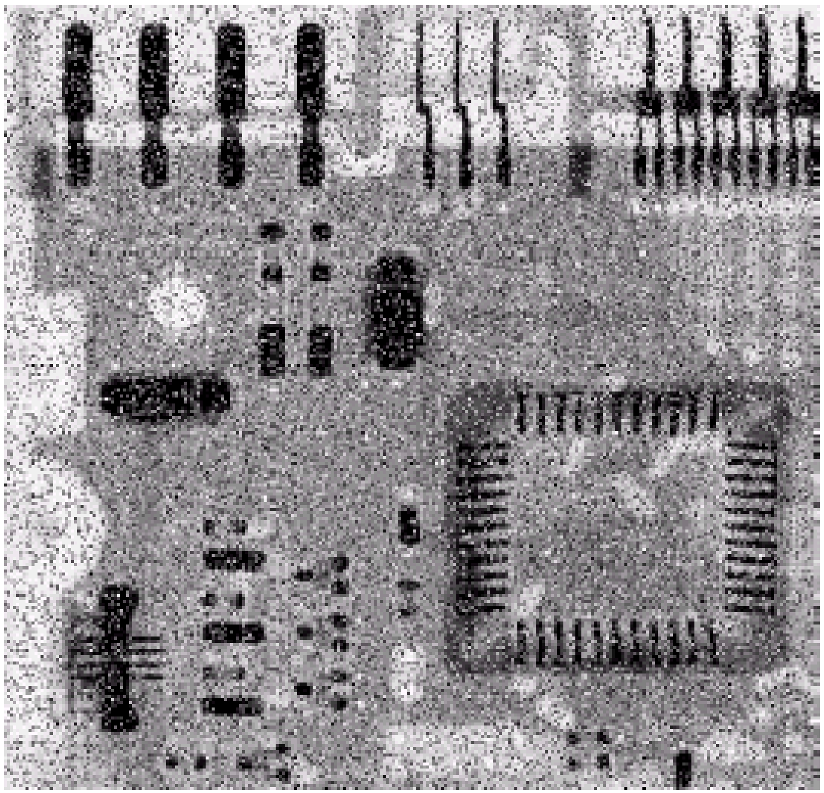
Image Enhancement Examples

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

Image Enhancement Examples (cont…)

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

Image Enhancement Examples (cont…)



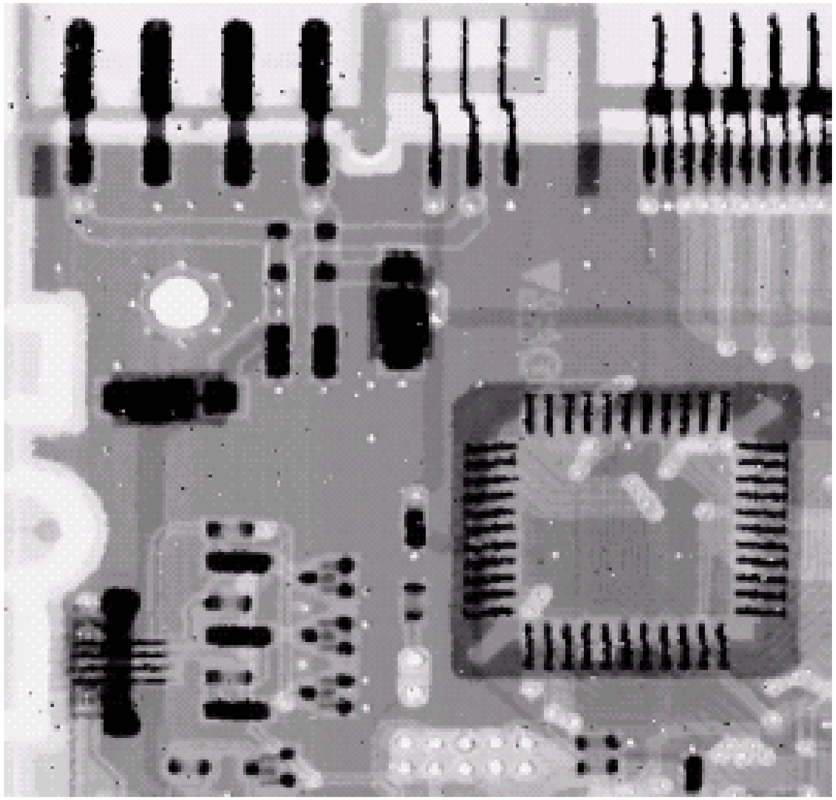
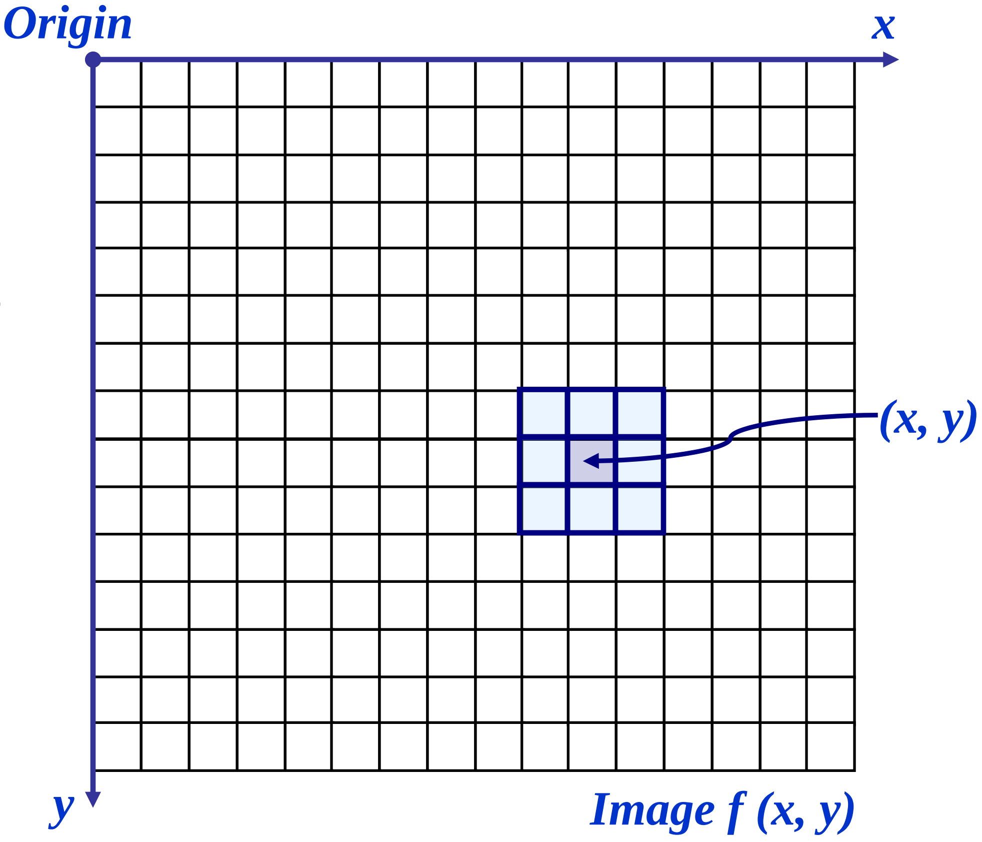


Image Enhancement Examples (cont…)

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

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

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

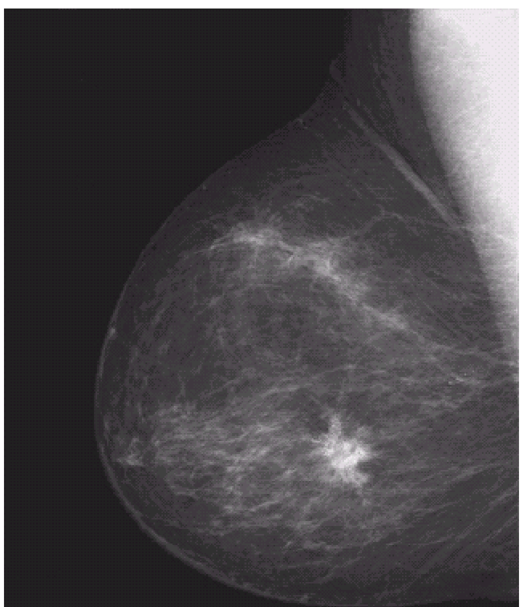
– The range [0,255] stems from display technologes

We need not be restricted to this range. For many of the image processing operations in this lecture grey levels are assumed to be given in the range [0.0, 1.0]

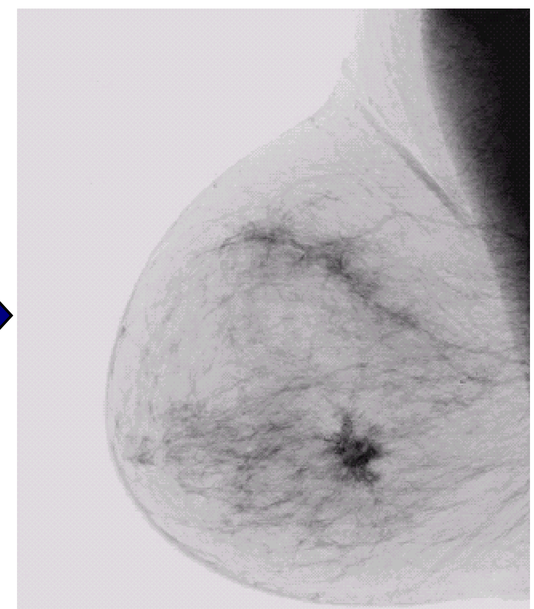
Point Processing Example: Negative Images

- Negative images are useful for enhancing white or grey detail embedded in dark regions of an image
  - Related to human visual perception and adaptation in different brightness range

Original Image



$s = 1.0 - r$

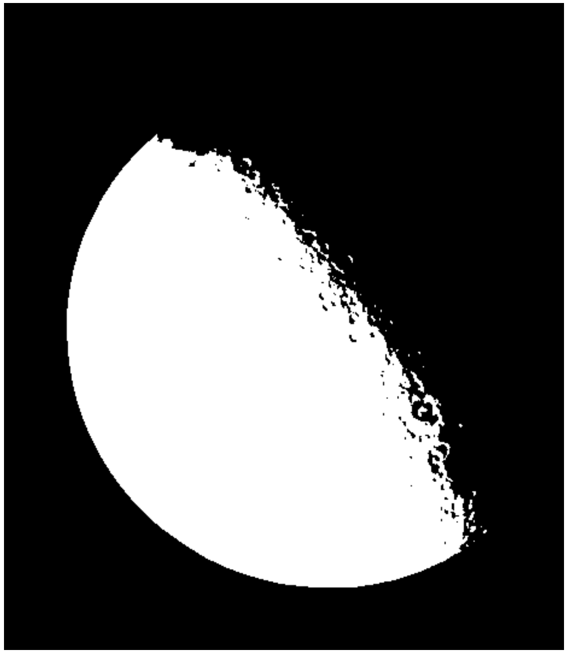


Negative Image

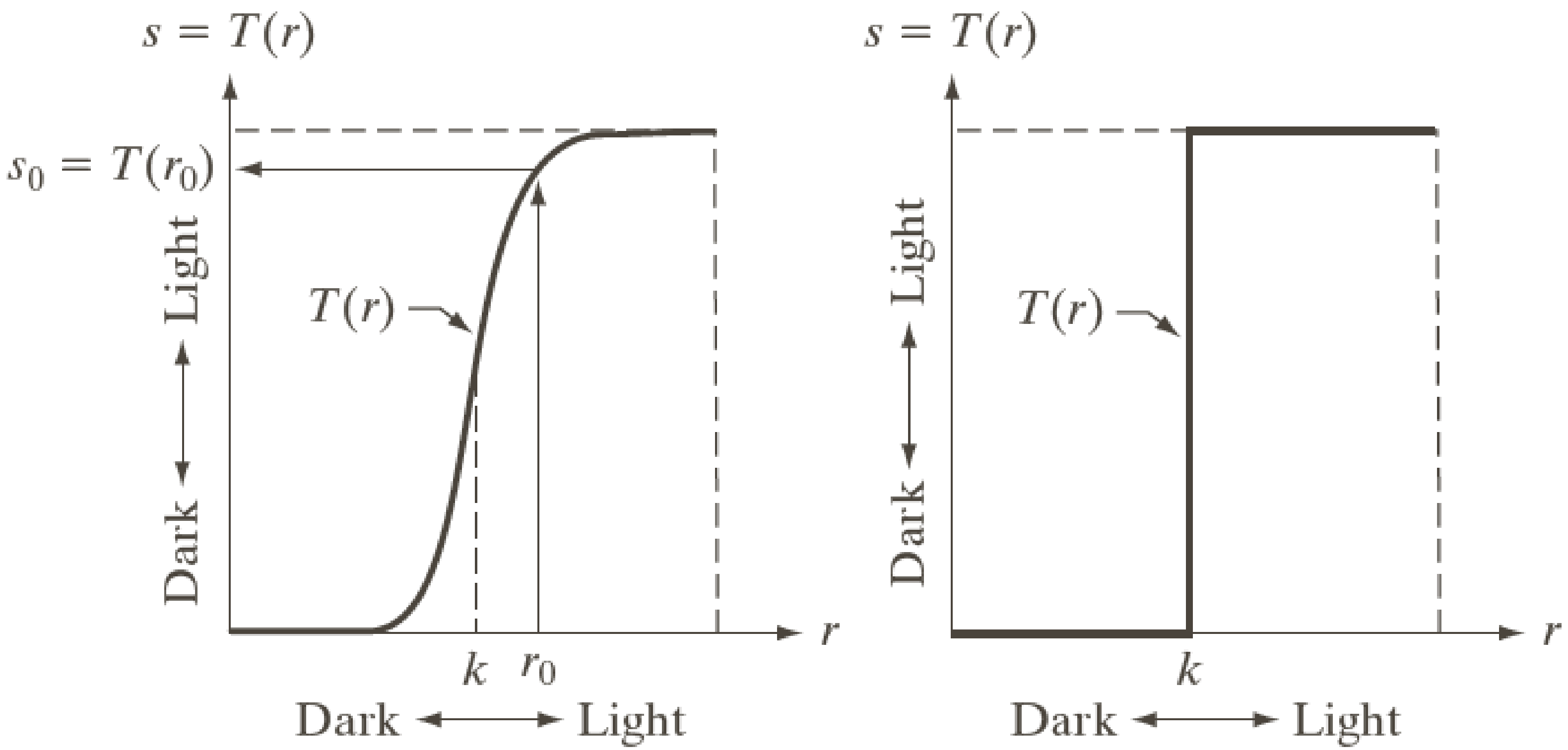
Point Processing Example: Thresholding

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

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

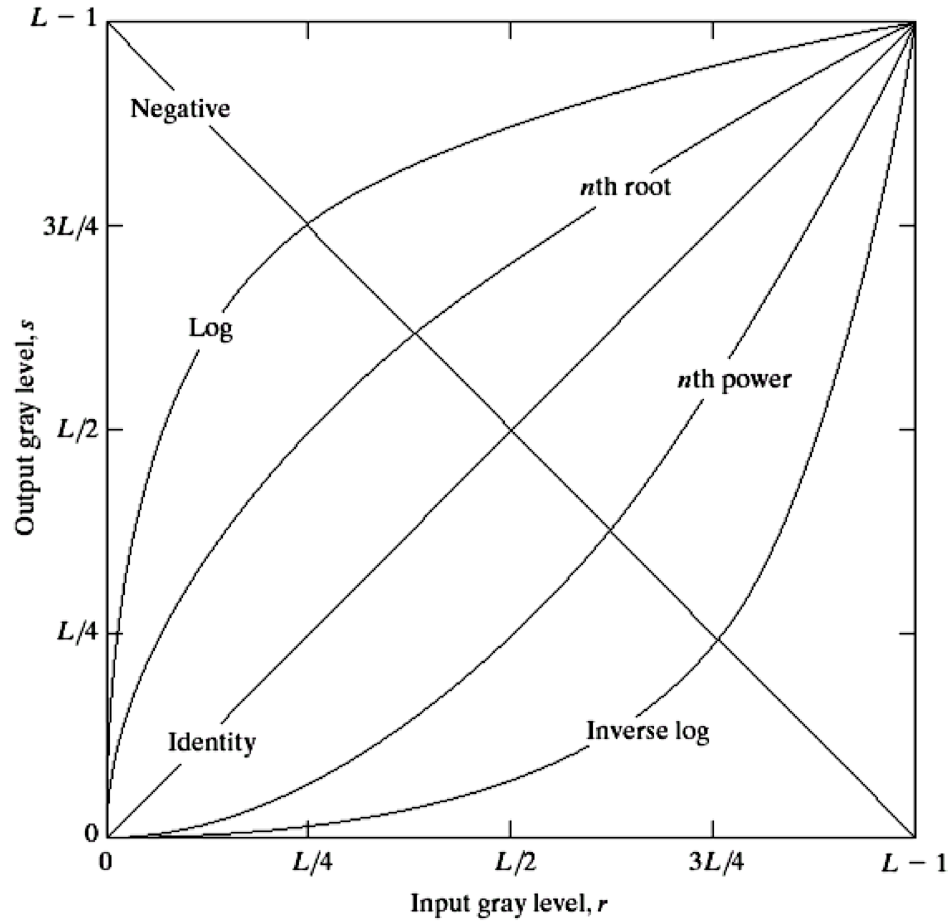


Intensity Transformations



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

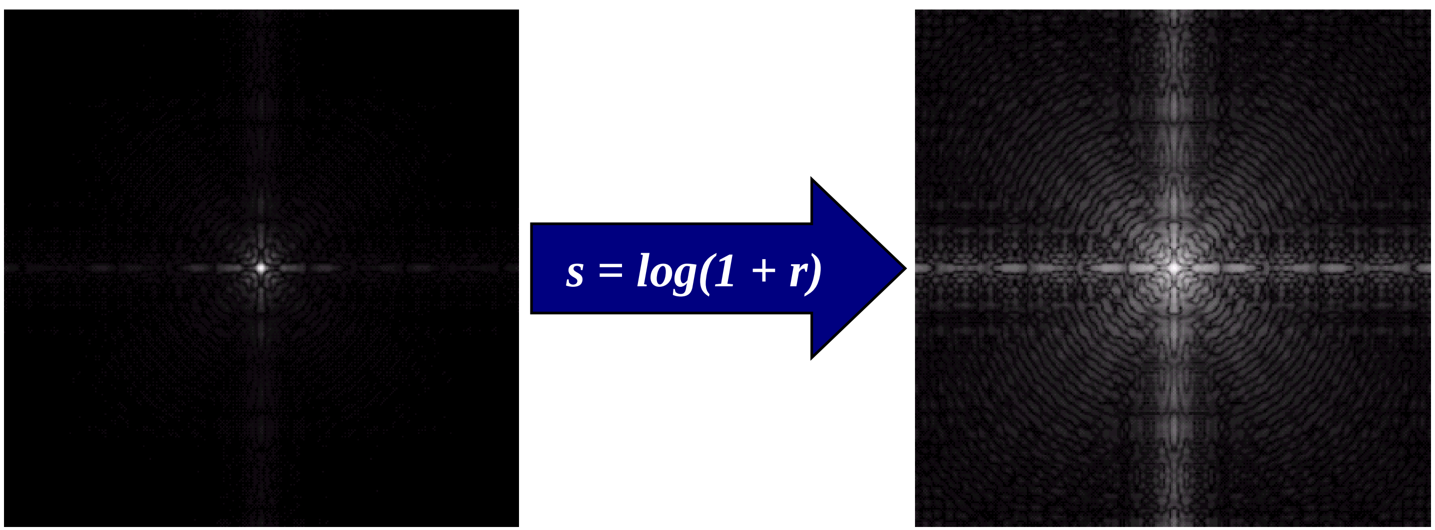


Logarithmic Transformations

- The general form of the log transformation is
  - $s = c * log(1 + r)$
- We usually set c to 1 and it is assumed that r >=0
- 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

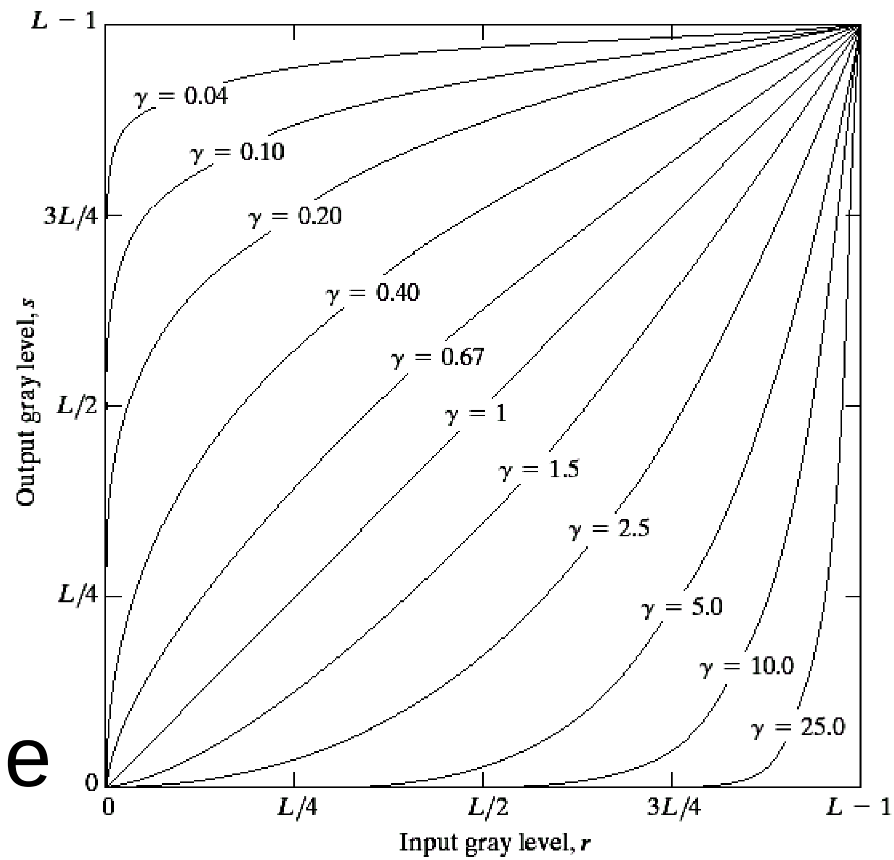


Power Law Transformations

- Power law transformations have the following form

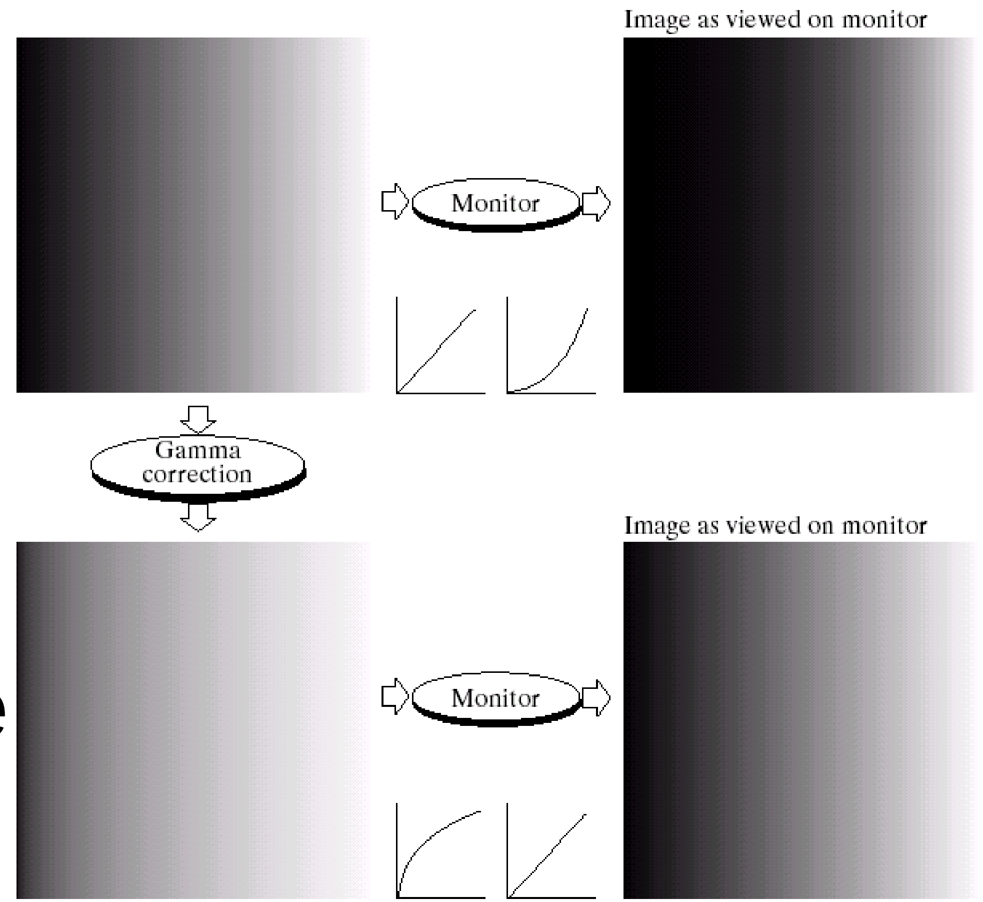
$$s = c * r^{\gamma}$$

- 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



Gamma Correction

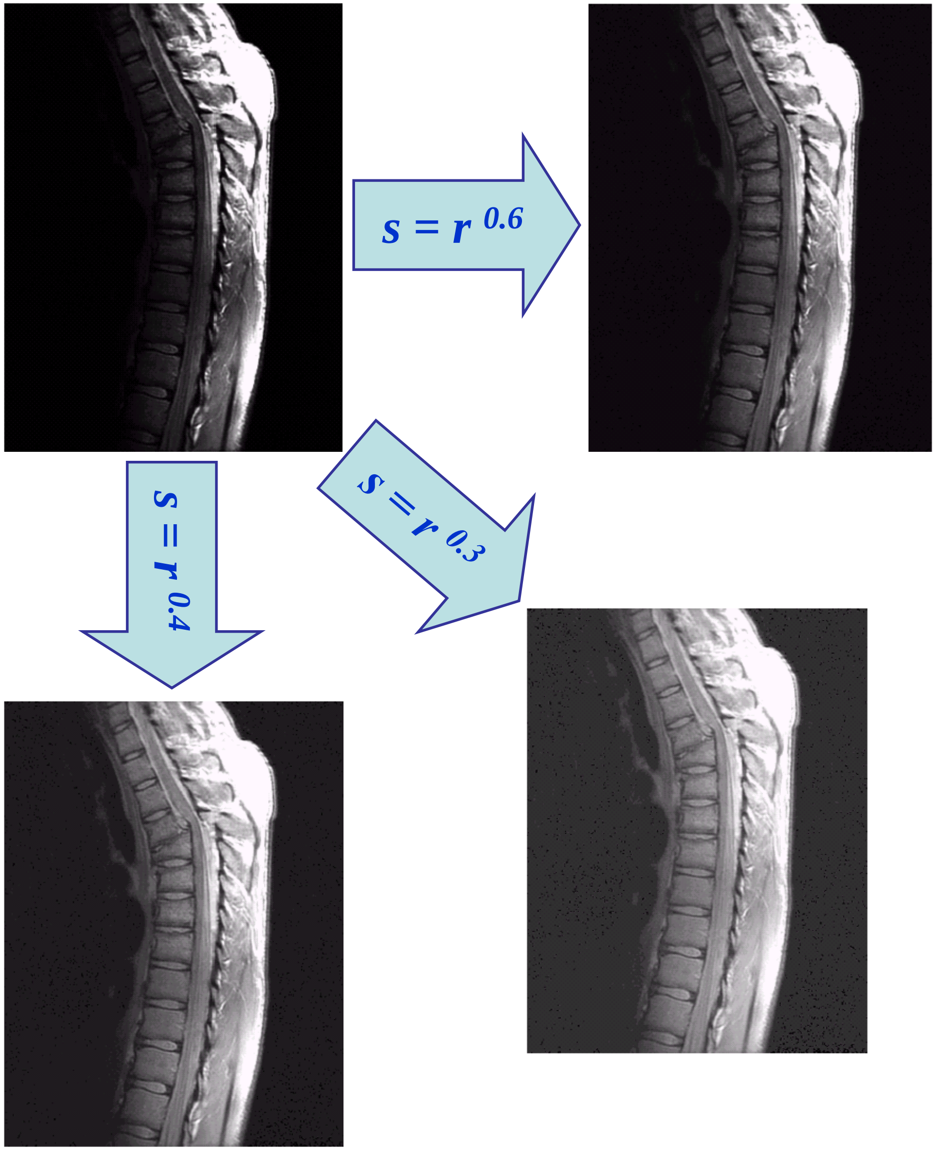
- Some of you might be familiar with gamma correction of computer monitors
- Problem is that display devices do not respond linearly to different intensities
- Can be corrected by preprocessing the image appropriately



Power Law Example

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

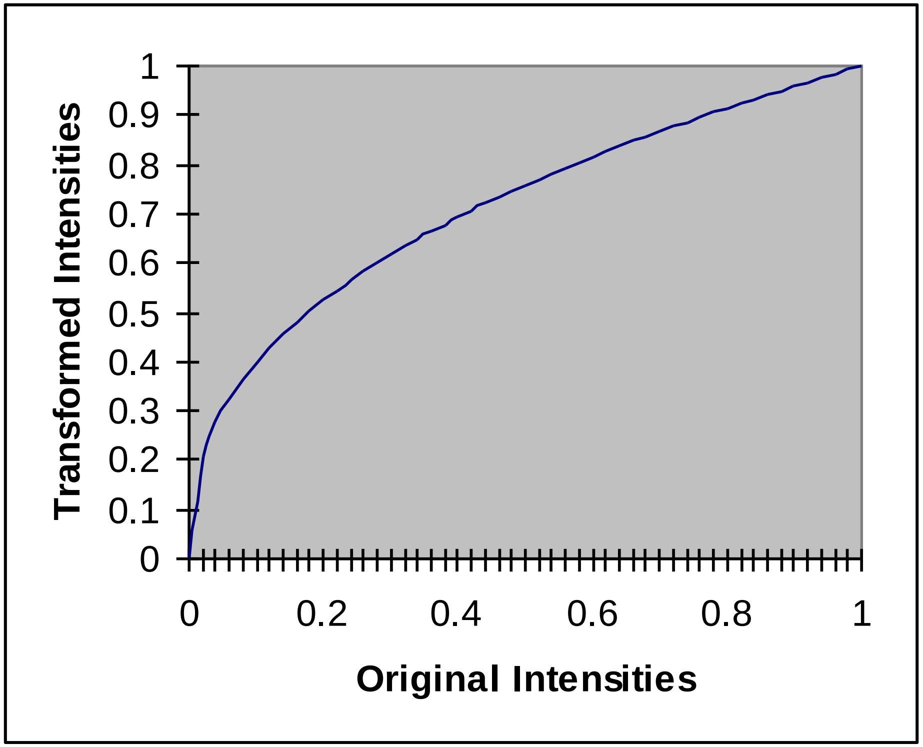


Power Law Example (cont…)

$\gamma = 0.6$

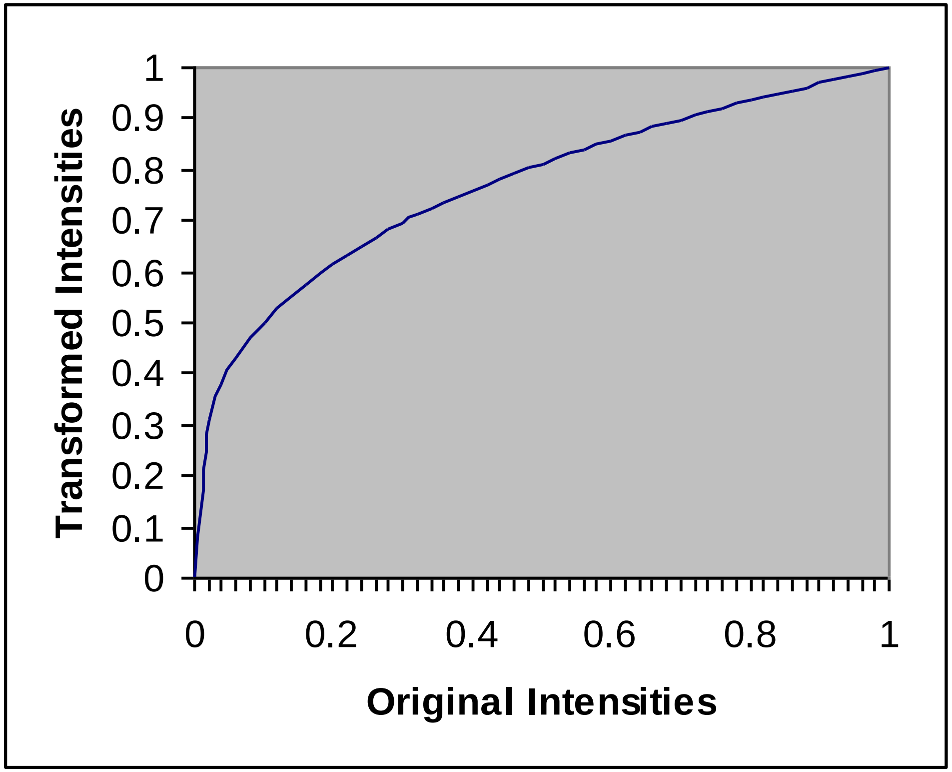
Power Law Example (cont…)

$$\gamma = 0.4$$



Power Law Example (cont…)

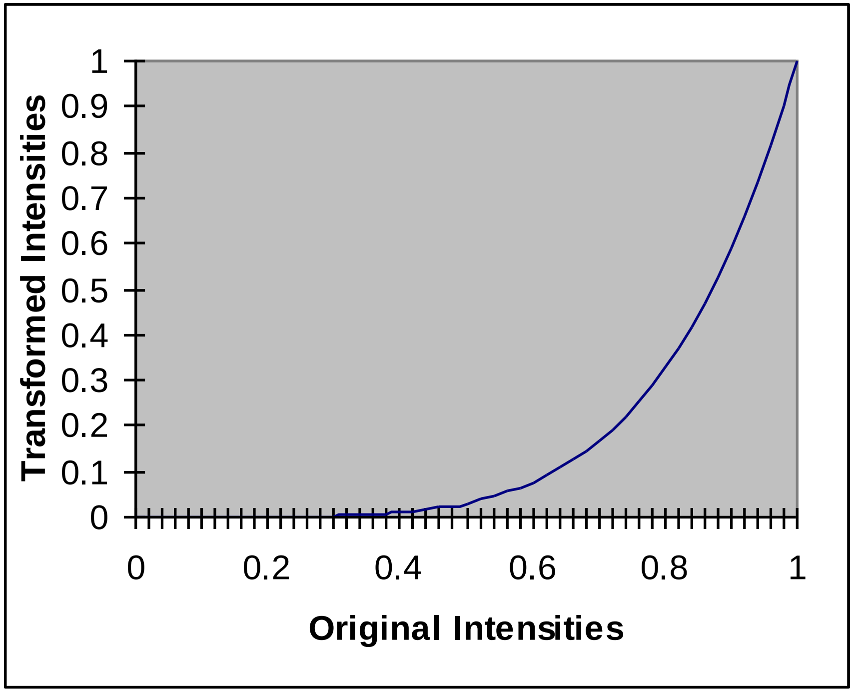
$$\gamma = 0.3$$



Power Law Example

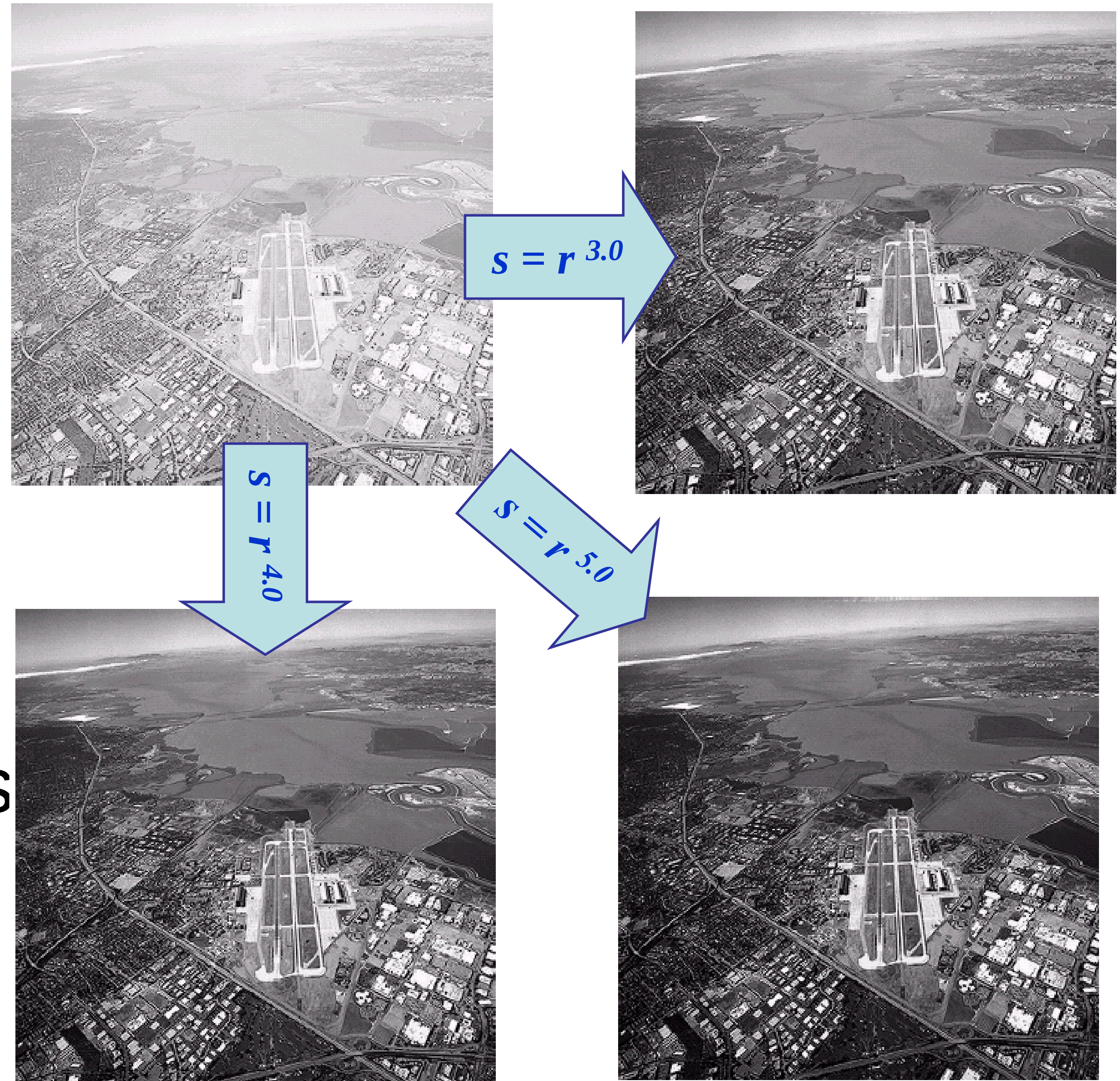
Power Law Example (cont…)

$$\gamma = 5.0$$



Power Law Transformations (cont…)

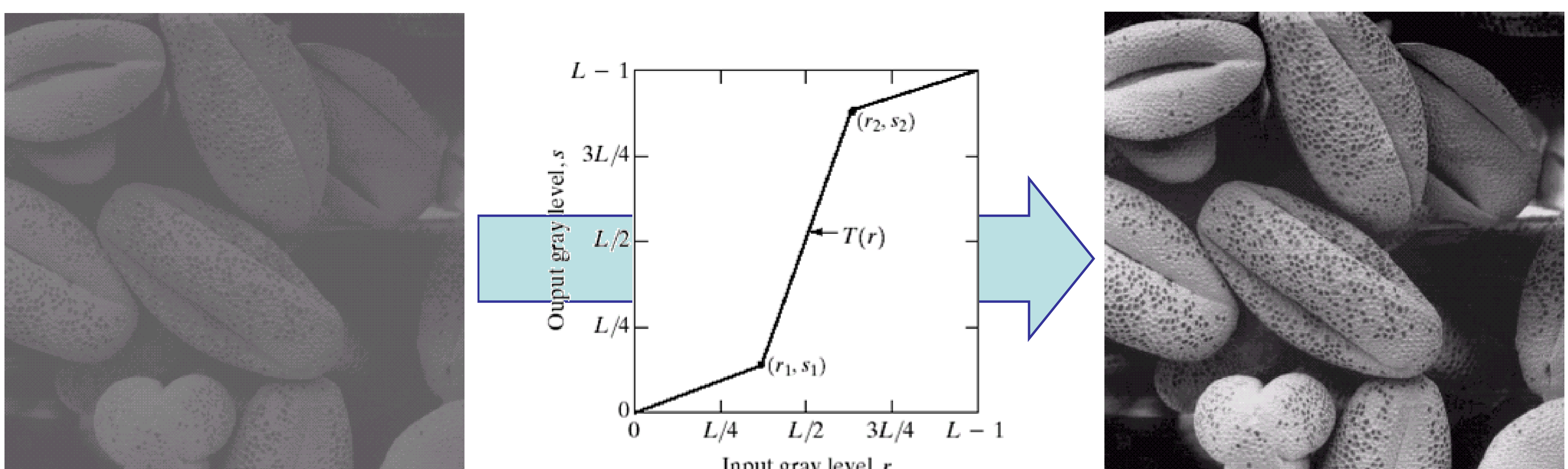
- An aerial photo of a runway is shown
- This time power law transforms are used to darken the image
- Different curves highlight different detail



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

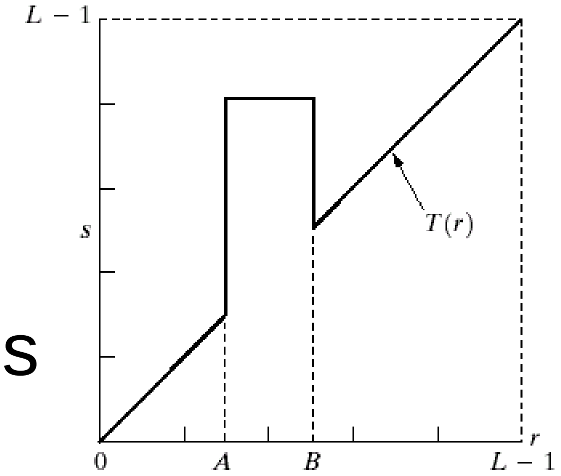
Piecewise Linear Transformation Functions

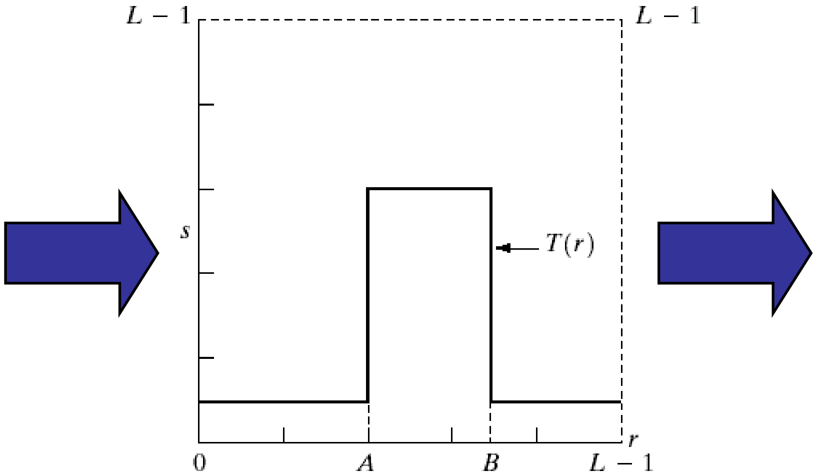
- Rather than using a well defined mathematical function we can use arbitrary user-defined transforms
- The images below show a contrast stretching linear transform to add contrast to a poor quality image



Gray Level Slicing

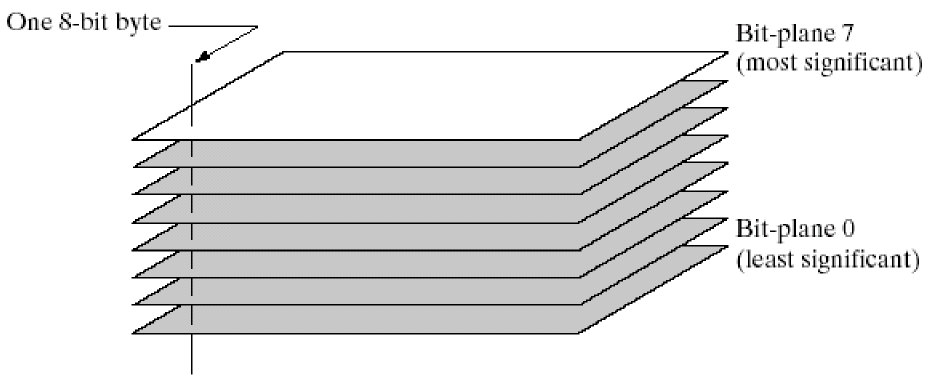
- Highlights a specific range of grey levels
  - Similar to thresholding
  - Other levels can be suppressed or maintained
  - Useful for highlighting features in an image

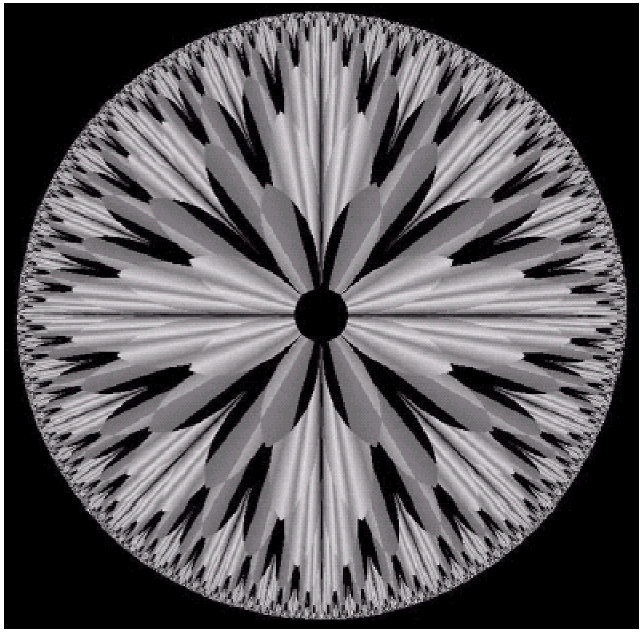




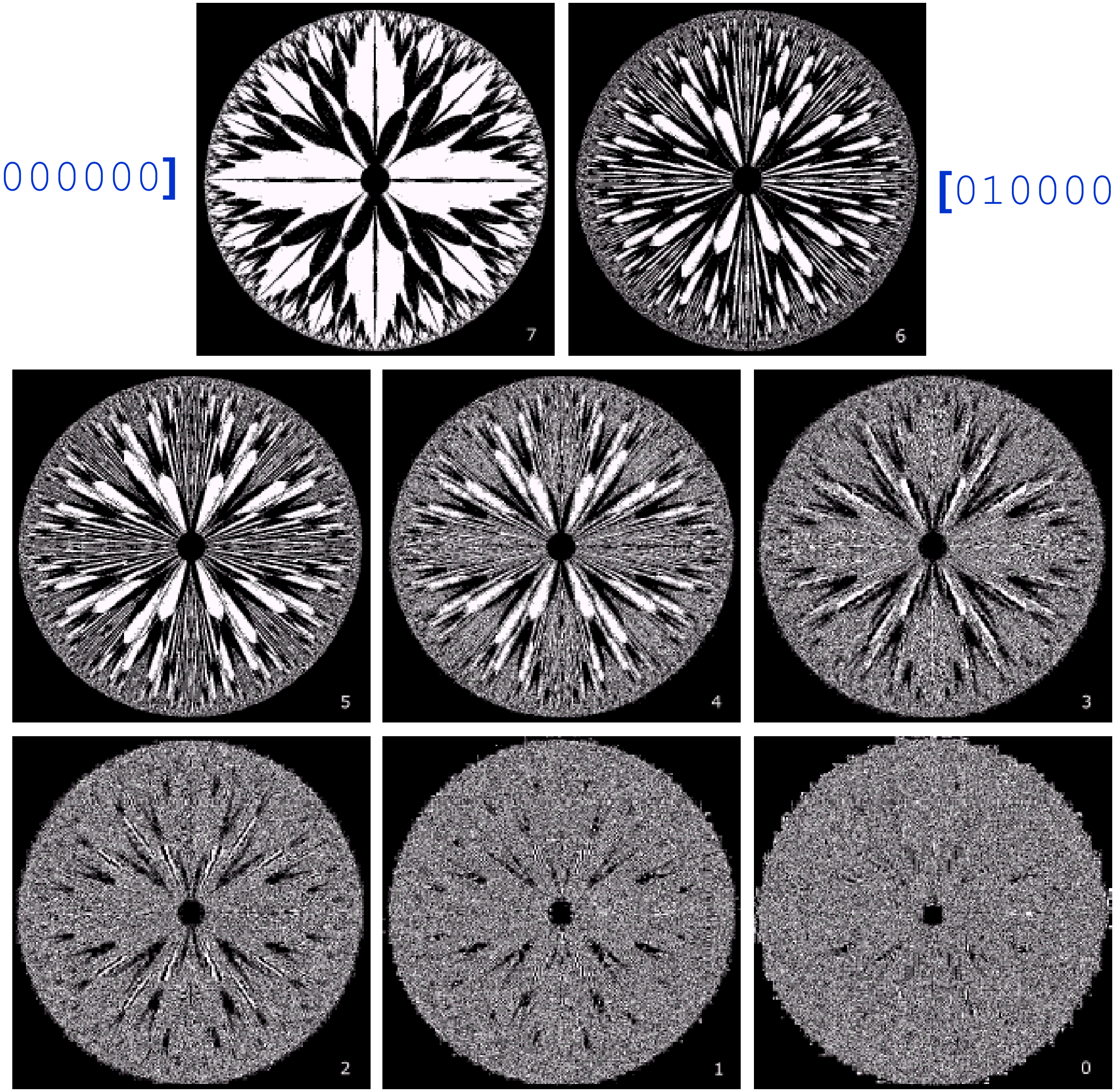
Bit Plane Slicing

- 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





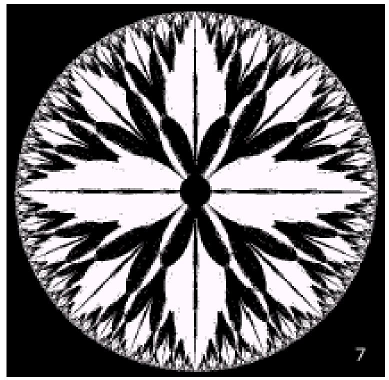
Bit Plane Slicing (cont…)

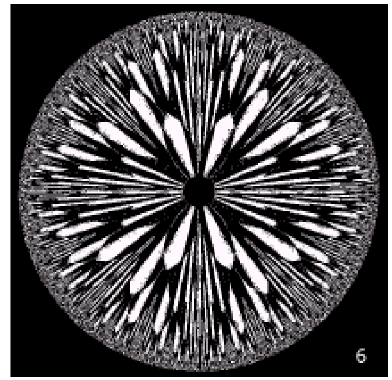


[10000000]
[01000000]
[00100000]
[00001000]
[00000100]
[00000001]

Bit Plane Slicing (cont…)

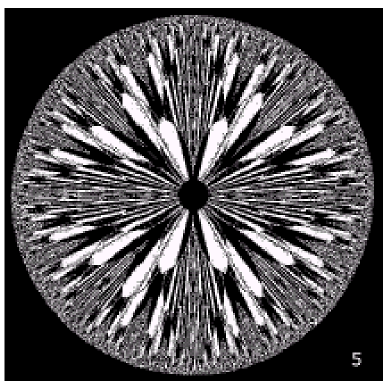
[10000000]

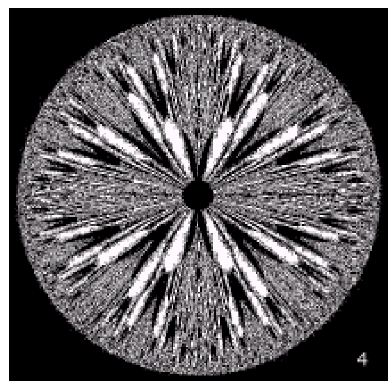


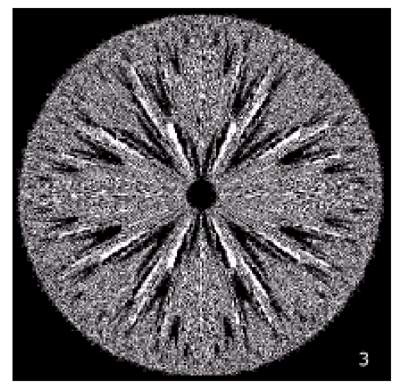


[01000000]

[00100000]

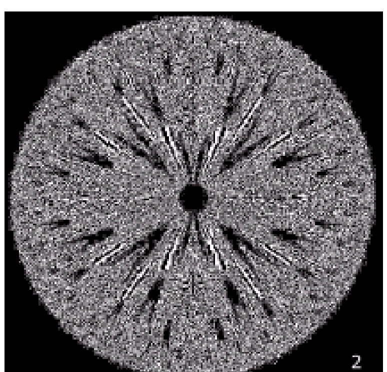


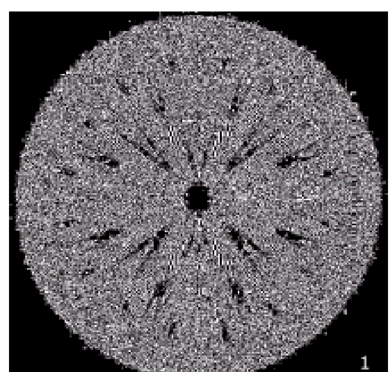


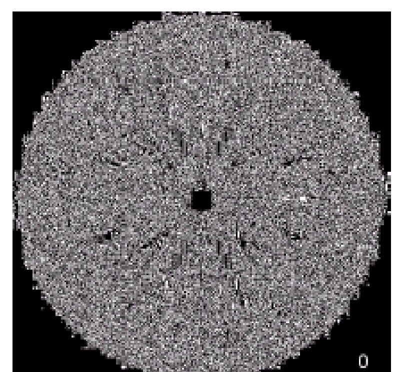


[00001000]

[00000100]







[00000001]

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

Bit Plane Slicing (cont…)

a b c
d e f
g h i

FIGURE 3.14 (a) An 8-bit gray-scale image of size 500 × 1192 pixels. (b) through (i) Bit planes 1 through 8, with bit plane 1 corresponding to the least significant bit. Each bit plane is a binary image.

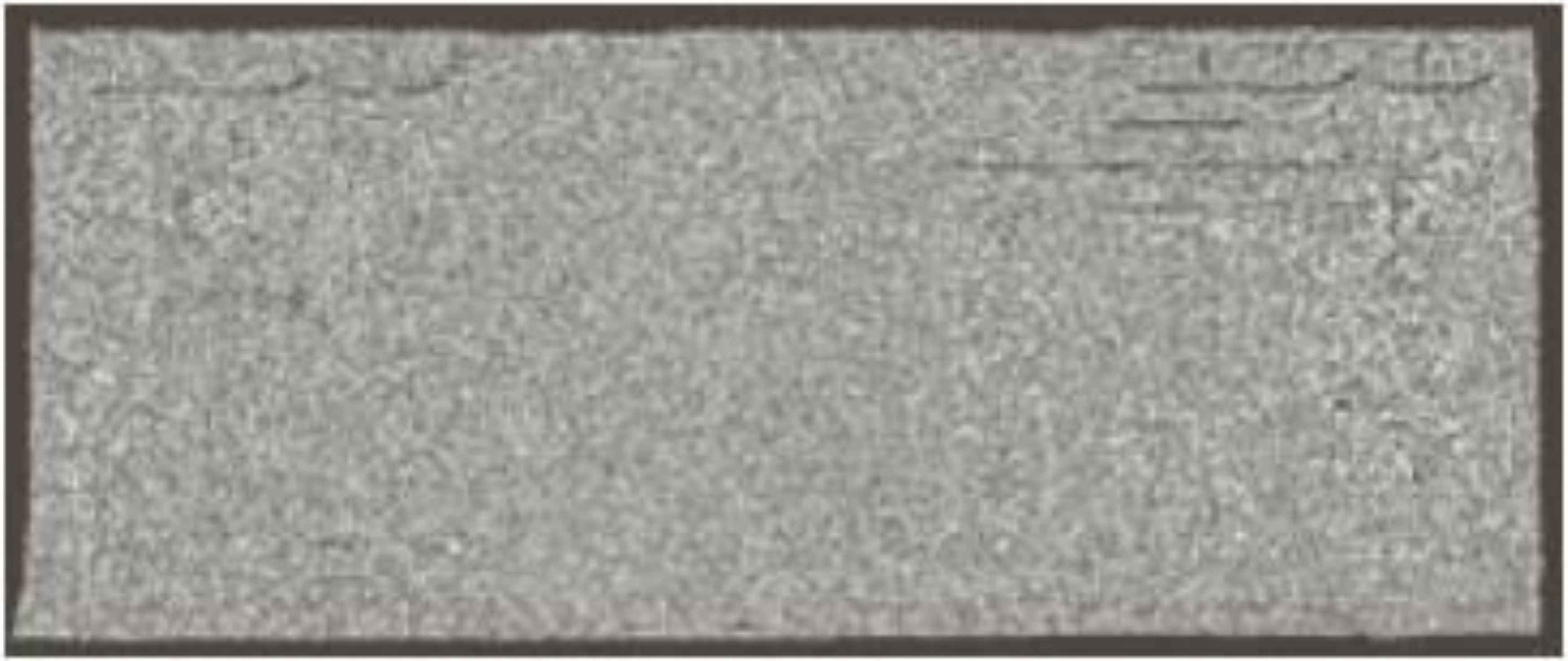
Bit Plane Slicing (cont…)

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

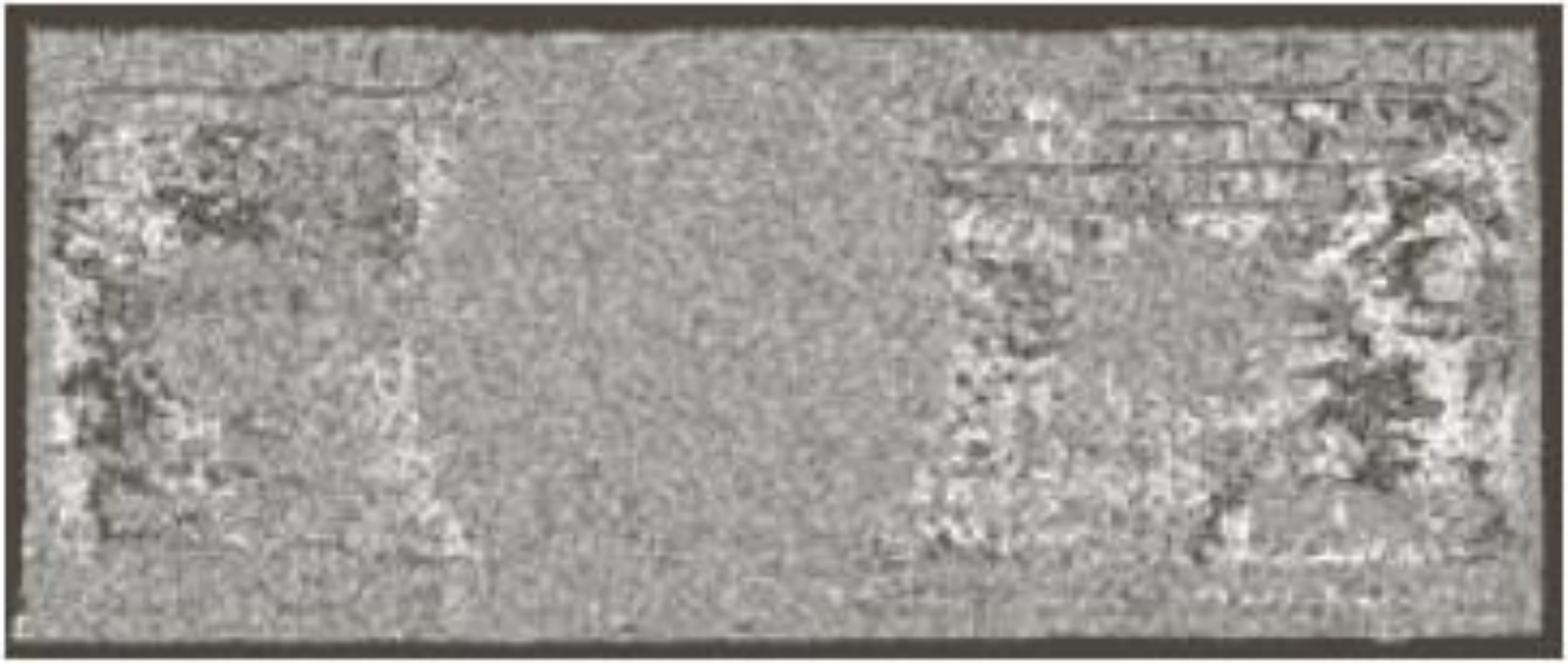
Bit Plane Slicing (cont…)

Bit Plane Slicing (cont…)

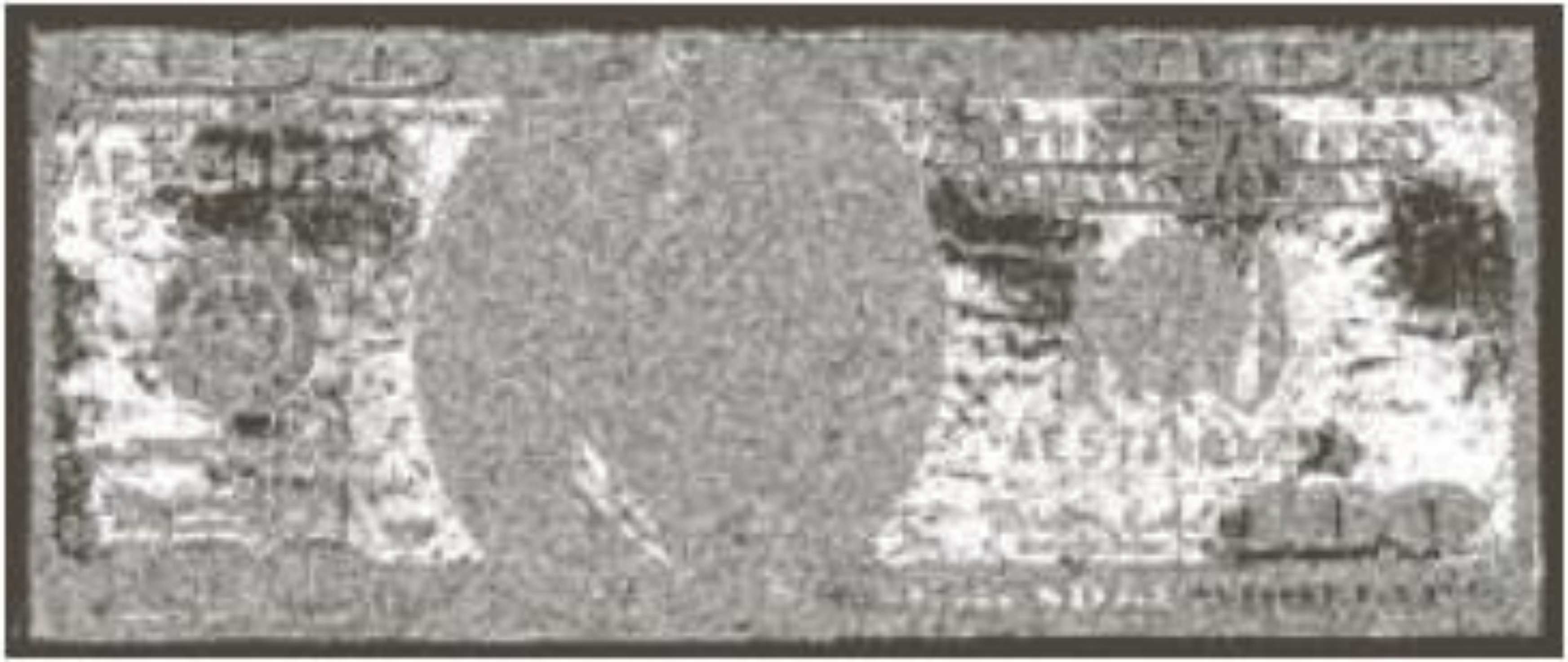
Bit Plane Slicing (cont…)



Bit Plane Slicing (cont…)



Bit Plane Slicing (cont…)



Bit Plane Slicing (cont…)

Bit Plane Slicing (cont…)

Bit Plane Slicing (cont…)

Bit Plane Slicing (cont…)

Reconstructed image using only bit planes 8 and 7

Reconstructed image using only bit planes 8, 7 and 6

Reconstructed image using only bit planes 7, 6 and 5

Summary of Point Processing Enhancement

- We have looked at different kinds of point processing image enhancement
  - Negative images
  - Thresholding
  - Logarithmic transformation
  - Power law transforms
  - Grey level slicing
  - Bit plane slicing

Next lecture we will see histogram based processing techniques