Introduction to Digital Image Processing

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Image Enhancement

- Processing an image to enhance certain features of the image
  - The result is more suitable than the original image for certain specific application.
- Processing techniques are very much problem oriented.
- Best technique for enhancement of X-ray image may not be the best for enhancement of microscopic images

Different Enhancement Techniques

Enhancement techniques fall under two broad categories

- Spatial Domain Technique
- Frequency Domain Techniques

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  - Direct manipulation of pixels in an image
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- Spatial Domain Technique
  - Work on image plane itself
  - Direct manipulation of pixels in an image
- Frequency Domain Techniques
  - Modify Fourier Transform coefficient of an image
  - Take inverse Fourier Transform of the modified coefficient to obtain the enhanced image.

Spatial Domain Technique

- Work directly on image pixels
- Functions can be expressed in the form

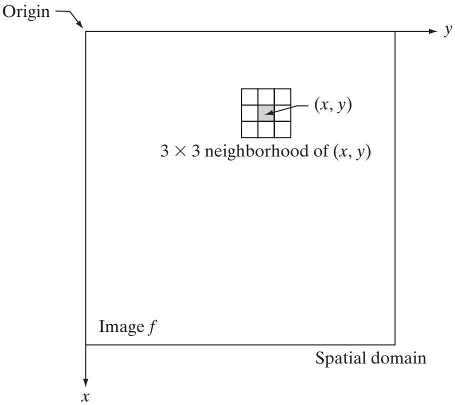
$$g(x, y) = T[f(x, y)]$$

  where $f(x, y)$ is input image,
  $g(x, y)$ is processed image.

- $T \Rightarrow$ Operator on $f(x, y)$ defined over some neighborhood of (x, y), applied at each pixel location (x, y) to generate the output image $g(x, y)$ at that location.
- T can also operate on a set of input images
  - Difference of two images,
  - Average of a number of images

Neighborhood

- The neighborhood about point (x, y) is usually a square subimage area centered at (x, y).



- Point processing (Intensity transformation)

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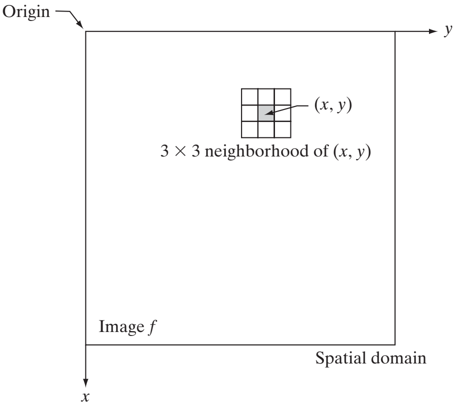


- Point processing (Intensity transformation)
- Mask processing (Spatial filtering)

Point Processing

- Point processing $\Rightarrow$ Neighborhood size is 1×1
- $g(x, y)$ depends only on the value of $f(x, y)$ at (x, y) here T is a gray level transformation function

$$s = T(r)$$

- s and r are gray levels of $g(x, y)$ and $f(x, y)$ at pixel location (x, y).
- $0 \geq s \geq 255$ and $0 \geq r \geq 255$

Point Processing

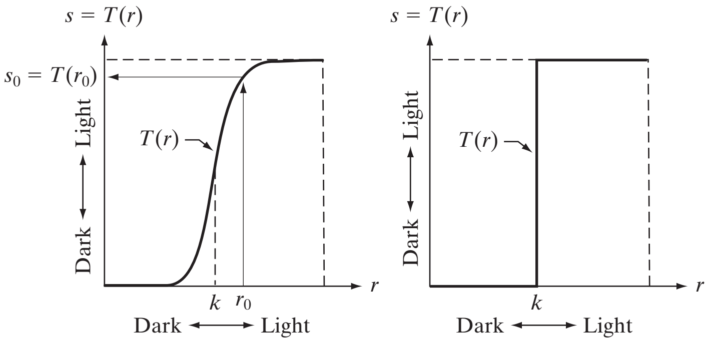


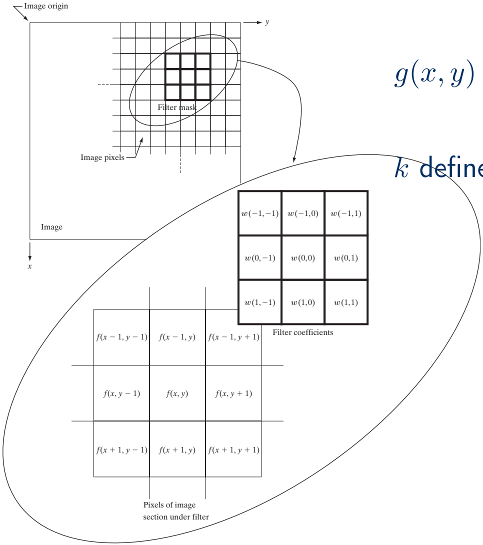
Figure: Intensity transformation functions (a) Contrast stretching function, (b) Thresholding function

Spatial Domain Techniques

Mask processing $\Rightarrow$ Neighborhood size is larger. $g(x, y)$ depends on the value of $f(x, y)$ in a predetermined neighborhood of (x, y)

- Mask is a small 2-D array.
- Values of the coefficient in this mask determines the nature of the process.
- For example sharpening, smoothing, filtering etc.

Mask Processing



$$g(x,y)=\sum_{j=-k}^{k}\sum_{j=-k}^{k} w(i,j)\cdot f(x+i,y+j)$$

k defines the size of the mask

Intensity Transformation Functions

- Contrast stretching
- Intensity-level slicing
- Bit-plane slicing

Contrast stretching

- Low contrast image can result from
  - Poor illumination of the scene
  - Lack of *dynamic range* of imaging sensor
  - Wrong setting of lens aperture during image acquisition
- Contrast stretching increases the dynamic range of gray levels in low contrast ranges.

Contrast stretching

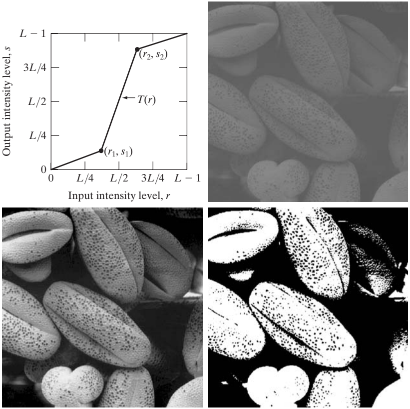
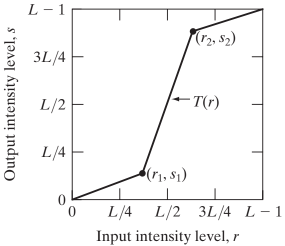


Figure: Contrast stretching. (a) Form of transformation function. (b) A low-contrast image. (c) Result of contrast stretching. (d) Result of thresholding.

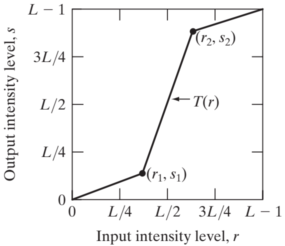
Contrast stretching

- $r_1 = s_1$ & $r_2 = s_2$
  produces no change in gray levels



Contrast stretching

- $r_1 = s_1$ & $r_2 = s_2$
  produces no change in gray levels
- $r_1 = r_2$ & $s_1 = 0$ & $s_2 = L - 1$
  Thresholding function producing binary image



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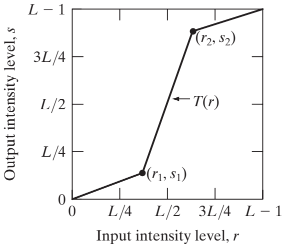
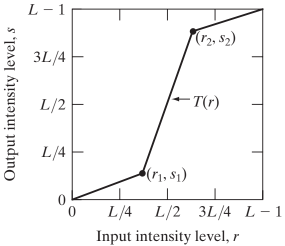
  Thresholding function producing binary image
- Intermediate value of (r_1, s_1) & (r_2, s_2)
  produce various degrees of spread in gray levels of the output image.



Contrast stretching



- $r_1 = s_1$ & $r_2 = s_2$
  produces no change in gray levels
- $r_1 = r_2$ & $s_1 = 0$ & $s_2 = L - 1$
  Thresholding function producing binary image
- Intermediate value of (r_1, s_1) & (r_2, s_2)
  produce various degrees of spread in gray levels of the output image.
- In general $r_1 \leq r_2$ and $s_1 \leq s_2$
  - Single valued and monotonically increasing function
  - Preserves order of gray levels, thus prevents creation of intensity artifacts in processed output.

Dynamic Range Compression

- Mainly needed for display purpose.
- Dynamic range of input image is so high that it exceeds that capability of display device
- Only brightest part is visible on the display screen
- Use *logarithmic transform* to compress dynamic range

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

where c scaling constant, and $r \geq 0$.

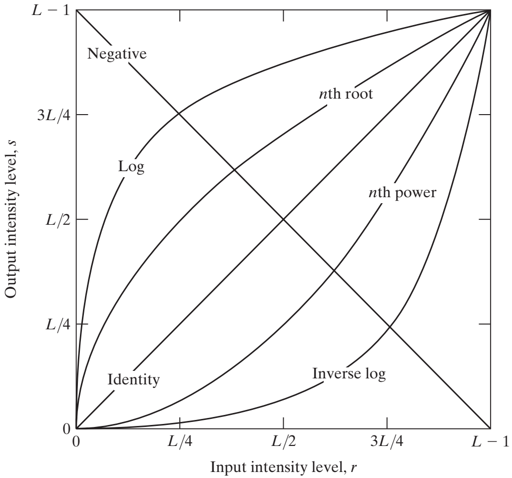
Log Transformation

- The general form of the log transformation

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

where c is a constant, and $r \geq 0$

- Log transform expand values of dark pixels while compressessing the higher-level values.



Log Transformation

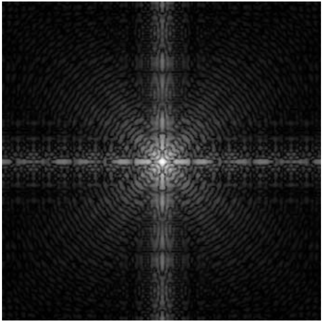


Figure: (a) Fourier spectrum. (b) Result of applying the log transformation with $c = 1$

Image Negatives

- The negative of an image with intensity levels in the range $[0, L-1]$ is obtained by using the *negative transformation*.

$$s = L - 1 - r$$

- Reversing intensity image produces the equivalent of a photographic negative
- Suitable for enhancing white or gray detail embedded in dark regions

Image Negatives

- Result shows a digital mamogram showing a small lesion
- It is easier to analyze the breast tissue in the negative image
- Very useful for displaying medical images

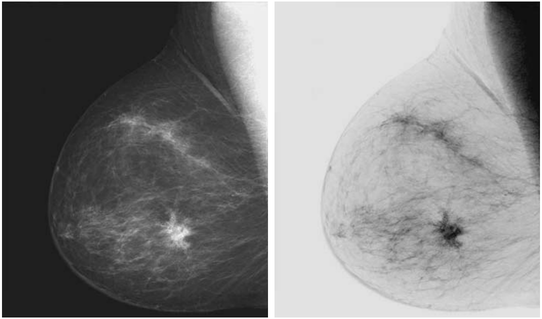


Figure: (a) Original digital mammogram. (b) Negative image obtained using the negative transformation

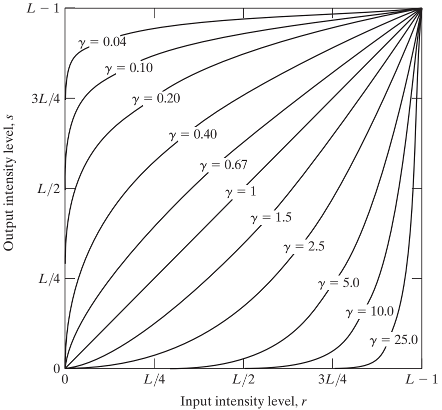
Power-Law (Gamma) Transformations

- *Power-law transformation* have the basic form

$$s = cr^{\gamma}$$

where c and γ are positive constants.

Imaging devices - Capturing, Printing, Display, $c = 1$



Power-Law (Gamma) Transformations

- *Power-law transformation* have the basic form

$$s = cr^{\gamma}$$

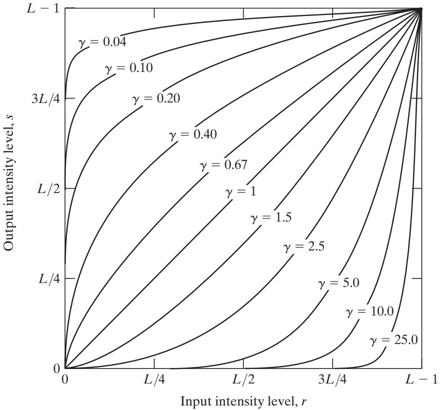
where c and γ are positive constants.

- Sometimes previous equation can be written as

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

to account for an offset.

Imaging devices - Capturing, Printing, Display, $c = 1$



Power-Law (Gamma) Transformations

$\gamma < 1 \Rightarrow$ Narrow range of dark input values is mapped into wider range of values
Wide range of high intensity values is mapped into narrow range of values
(similar to log-transformation)

$\gamma > 1 \Rightarrow$ Genereate opposite effects

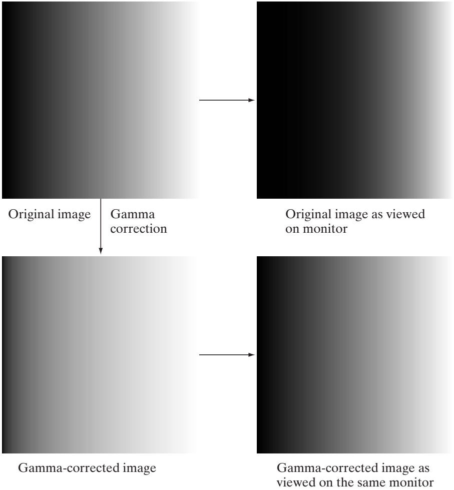
$\gamma = 1, \ c = 1 \Rightarrow$ Leads to *identity transformation*

- Image capture, printing and display devices respond according to power-law
- Conventionally the exponent is referred to as gamma
- Process used to correct this power-law is called *gamma correction*.

Example: Power-Law

- CRT Devices have an intensity to voltage relation which is a power function with exponent varying from 1.8 to 2.5
- From the plot ($\gamma = 2.5$) display system will produce images which are darker than intended
- A gray scale linear wedge input into a CRT monitor appears darker
- With gamma correction ($s = r^{\frac{1}{2.5}} = r^{0.4}$) display is close in appearance to input
- Same is true with other imaging devices (different values of gamma)

Power-Law (Gamma) Transformations



a b
c d

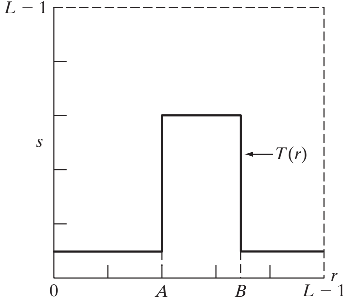
FIGURE 3.7
(a) Intensity ramp image. (b) Image as viewed on a simulated monitor with a gamma of 2.5. (c) Gamma-corrected image. (d) Corrected image as viewed on the same monitor. Compare (d) and (a).

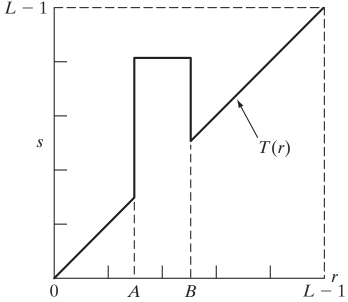
Power-Law (Gamma) Transformations

Figure: (a) Aerial image. (b)-(d) Results of applying the transformation with $c = 1$ and $\gamma = 3.0, 4.0$, and 5.0, respectively.

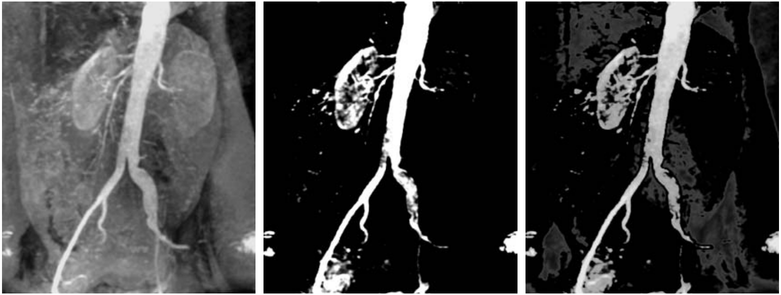
Graylevel Slicing

- Highlights specific range of gray levels in an image.
- Application
  - enhancing features such as vegetation area in satellite images.
  - detection of flaws in X-ray images etc.





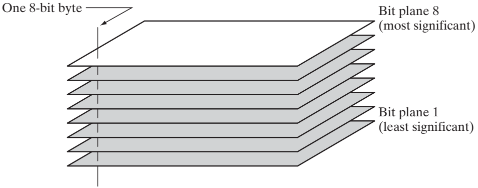
Graylevel Slicing



a b c

FIGURE 3.12 (a) Aortic angiogram. (b) Result of using a slicing transformation of the type illustrated in Fig. 3.11(a), with the range of intensities of interest selected in the upper end of the gray scale. (c) Result of using the transformation in Fig. 3.11(b), with the selected area set to black, so that grays in the area of the blood vessels and kidneys were preserved. (Original image courtesy of Dr. Thomas R. Gest, University of Michigan Medical School.)

Bit-plane slicing



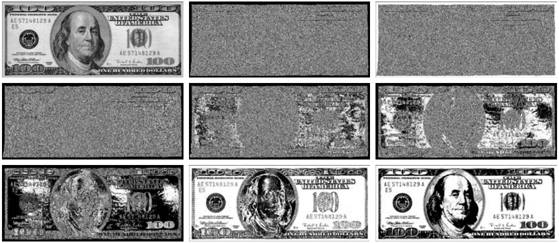


Figure: Bit-plane presentation of an 8-bit image.

Bit-plane slicing

a b c

FIGURE 3.15 Images reconstructed using (a) bit planes 8 and 7; (b) bit planes 8, 7, and 6; and (c) bit planes 8, 7, 6, and 5. Compare (c) with Fig. 3.14(a).

Thank You

Queries?