

PAM3012
Digital Image Processing for
Radiographers

Image Enhancement in the Spatial
Domain (Part I)

In this lecture

- ★ Image Enhancement
- ★ Introduction to spatial domain
- ★ Background Information
- ★ Greyscale transformations

Image Enhancement

- Processing of an image so that result is more suitable for specific application
- Two broad categories:
 1. Spatial domain
 2. Frequency domain

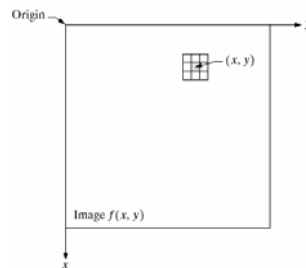
Background

- Procedures that operate directly on the aggregate of pixels composing an image

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

Background

- A neighborhood about (x,y) is defined by using a square subimage area centered at (x,y) .
- Operator T is applied to each location



Background

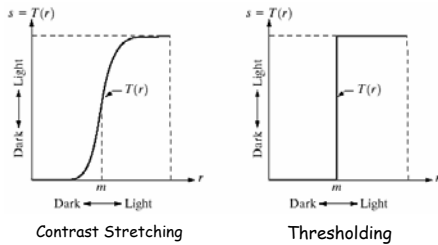
- Simplest form neighborhood is 1×1 pixels
- g depends only on value of f at (x,y)
- T becomes a gray-level transformation (or mapping) function:

$$s = T(r)$$

- r, s : gray levels of $f(x,y)$ and $g(x,y)$ at (x,y)
Called *Point processing*
– e.g. contrast stretching, thresholding

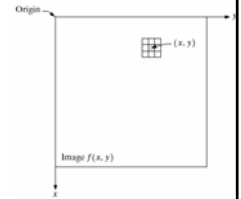
Background

- Gray-level transformation functions for contrast enhancement



Background

- If neighborhood is greater than 1×1
- Values of f in a predefined neighborhood of (x,y) determine the value of g at (x,y) .
- Values of surrounding pixels (mask) determine nature of process in each pixel
- Called *Mask processing* or *filtering*



Point Processing

- Methods based only on the intensity of single pixels.

$$s = T(r)$$

- r denotes the pixel intensity before processing.
- s denotes the pixel intensity after processing.

Basic Gray-Level Transformations

Examples of Point Processing

- Image Negatives
- Log Transformations
- Power-Law Transformations
- Piecewise Transformation
 - Contrast Stretching
 - Gray-level Slicing
 - Bit-plane Slicing
- Implemented via Look-Up Tables (LUT)
- T are stored in a 1-D array

Basic Gray-Level Transformations

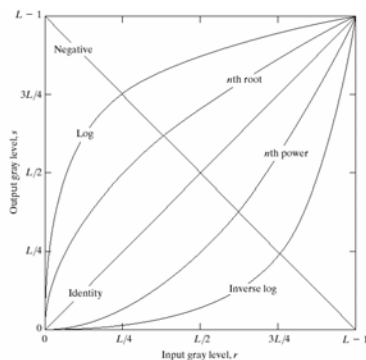


Image Negatives

- Obtained using the transformation function $s = T(r)$

- Function $s = L-1-r$
or
 $T(r) = L - 1 - r$

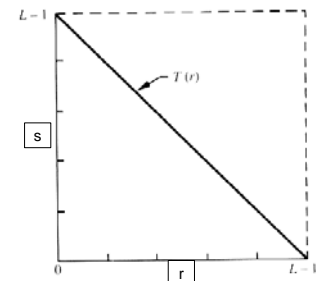
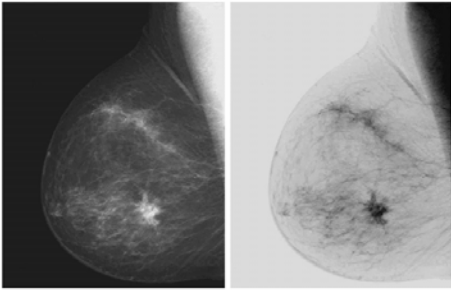


Image Negatives

Suited to enhancing white or gray detail in dark region

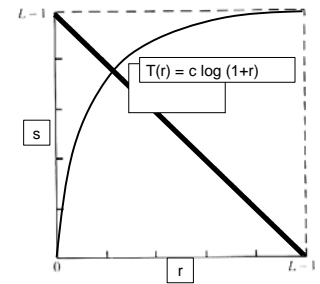


Log Transformations

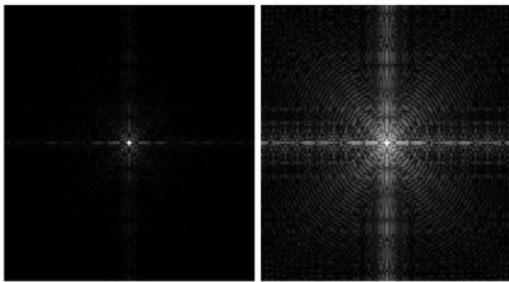
$$s = \log(1 + r) \times c$$

c is a constant

Compresses the dynamic range of images with large variations in pixel values



Log Transformations

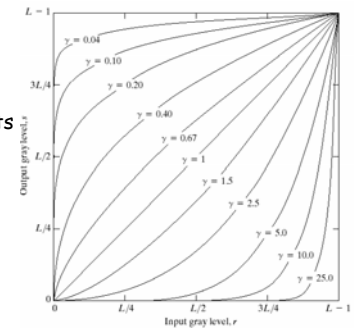


Power-Law Transformations

$$s = cr^\gamma$$

c, γ : positive constants

- Gamma correction



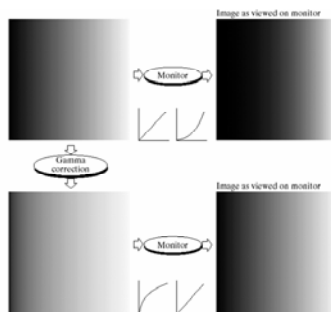
Power-Law Transformations

Gamma Correction

Display devices have response governed by power law

E.g. CRT intensity-to-voltage response governed by power law: γ 1.8 to 2.5

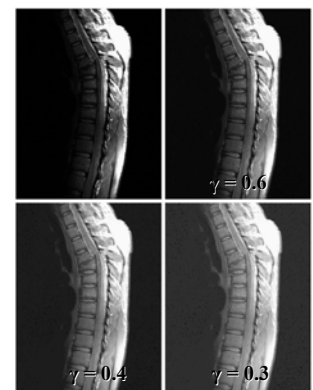
If display has γ of 2.5 LUT with γ of 0.4 is required



Power-Law Transformations

Gamma Correction

Also useful for general purpose contrast manipulation



Power-Law Transformations

Gamma Correction

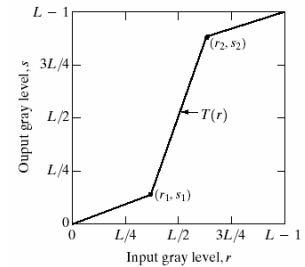
Also useful for general purpose contrast manipulation



Piecewise-Linear Transformation

Contrast Stretching

To increase the dynamic range of the gray levels in the image

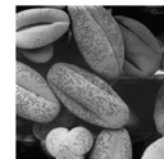
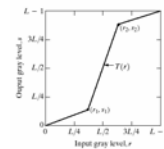
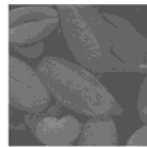


Contrast Stretching

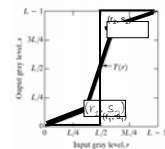
- The locations of (r_1, s_1) and (r_2, s_2) control the shape of the transformation function
 - If $r_1 = s_1$ and $r_2 = s_2$ the transformation is a linear function and produces no changes
 - If $r_1 = r_2$, $s_1 = 0$ and $s_2 = L-1$, the transformation becomes a thresholding function that creates a binary image

Piecewise-Linear Transformation

Low Contrast Image



Contrast Stretched



Thresholded

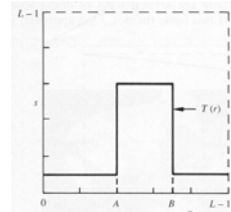
Contrast Stretching

- More on function shapes:
 - Intermediate values of (r_1, s_1) and (r_2, s_2) produce various degrees of spread in the gray levels of the output image, thus affecting its contrast.
 - Generally, $r_1 \leq r_2$ and $s_1 \leq s_2$ is assumed.

Gray-Level Slicing

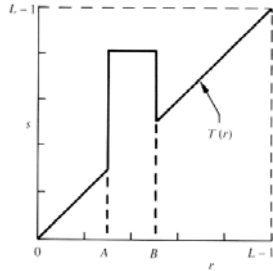
- To highlight a specific range of gray levels in an image
- I.e. Enhance certain features

One way is to display a high value for all gray levels in the range of interest and a low value for all other gray levels (binary image).

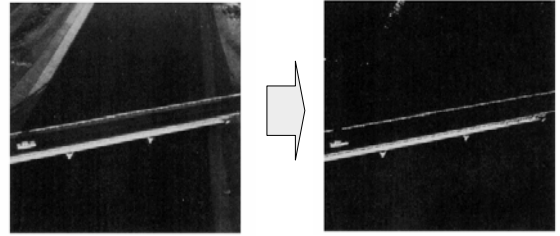
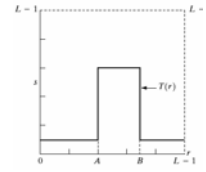


Gray-Level Slicing

Second approach is to brighten desired range of gray levels but preserve the background and gray-level tonalities in the image

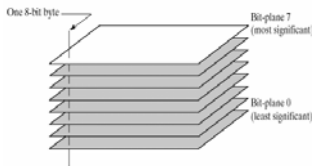


Gray-Level Slicing



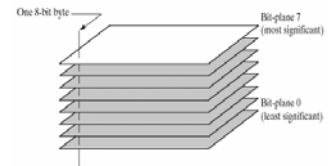
Bit-Plane Slicing

- Highlights the contribution made to the total image appearance by specific bits
- Example: Each pixel is represented by 8 bits, the image is composed of 8 1-bit planes.
- Plane 0 contains the least significant bit and plane 7 contains the most significant bit.

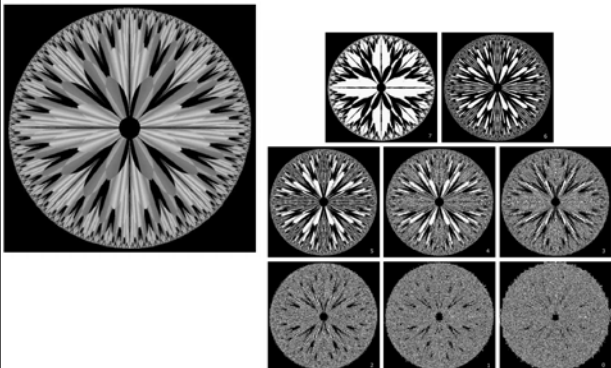


Bit-Plane Slicing

- Highlights the contribution made to the total image appearance by specific bits
- Only the higher order bits (top four) contain visually significant data. The other bit planes contribute the more subtle details.
- Plane 7 corresponds exactly with an image thresholded at gray level 128.



Bit-Plane Slicing



Summary

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Summary

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 - Bit-plane Slicing