



Lecture 12

Fourth stage

Medical Physical Department

Medical Imaging Processing

Image Enhancement

By

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Image Enhancement

- Image enhancement is the procedure of improving the quality and the information content of original data before processing.
- The principal objective of image enhancement is to process a given image so that the result is more suitable than the original image for a specific application.
- It accentuates or sharpens image features such as edges, boundaries, or contrast to make a graphic display more helpful for display and analysis.
- The enhancement doesn't increase the inherent information content of the data, but it increases the dynamic range of the chosen features so that they can be detected easily.
- Enhancement methods tend to be problem specific. For example, a method that is used to enhance satellite images may not be suitable for enhancing medical images.

Here are some examples of image enhancement:

- Smooth and sharpen
- Noise removal
- Deblur images
- Contrast adjustment
- Brighten an image
- Grayscale image histogram equalization

Image enhancement techniques can be divided into two broad categories:

Spatial domain — enhancement of the image space that divides an image into uniform pixels according to the spatial coordinates with a particular resolution. The spatial domain methods perform operations on pixels directly.

Frequency domain — enhancement obtained by applying the Fourier Transform to the spatial domain. In the frequency domain, pixels are operated in groups as well as indirectly.



Types of spatial domain operator:

1. **Point operation (intensity transformation)** – Point operations refer to running the same conversion operation for each pixel in a grayscale image. The transformation is based on the original pixel and is independent of its location or neighboring pixels.
2. **Spatial filter (or mask, kernel)** – The output value depends on the values of $f(x,y)$ and its neighborhood.

Point Operation

Point operations are often used to change the grayscale range and distribution. The concept of point operation is to map every pixel onto a new image with a predefined transformation function. $g(x, y) = T(f(x, y))$

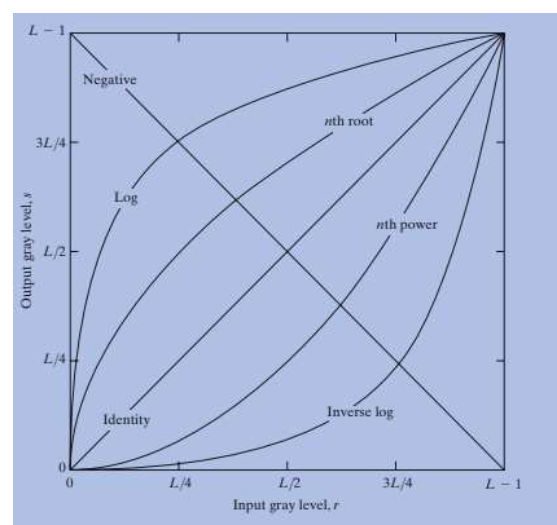
- $g(x, y)$ is the output image
- T is an operator of intensity transformation
- $f(x, y)$ is the input image

Basic Intensity Transformation Functions

The simplest image enhancement method is to use a 1×1 neighborhood size. It is a point operation. In this case, the output pixel ('s') only depends on the input pixel ('r'), and the point operation function can be simplified as follows: $s = T(r)$

Where T is the point operator of a certain gray-level mapping relationship between the original image and the output image. s, r : denote the gray level of the input pixel and the output pixel.

[Different transformation functions work for different scenarios:](#)

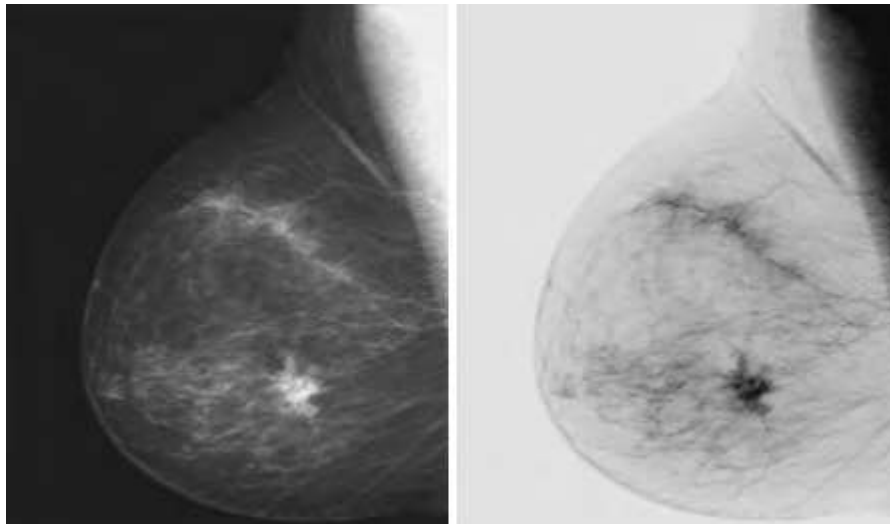


Linear

Linear transformations include *identity transformation* and *negative transformation*. In *identity transformation*, the input image is the same as the output image: $s = r$

The *negative transformation* is: $s = L - 1 - r = 256 - 1 - r = 255 - r$

L = Largest gray level in an image. The negative transformation is suited for enhancing white or gray detail embedded in dark areas of an image, for example, analyzing the breast tissue in a digital mammogram.



Logarithmic

a) General Log Transform

The equation of general log transformation is: $s = c * \log(1 + r)$

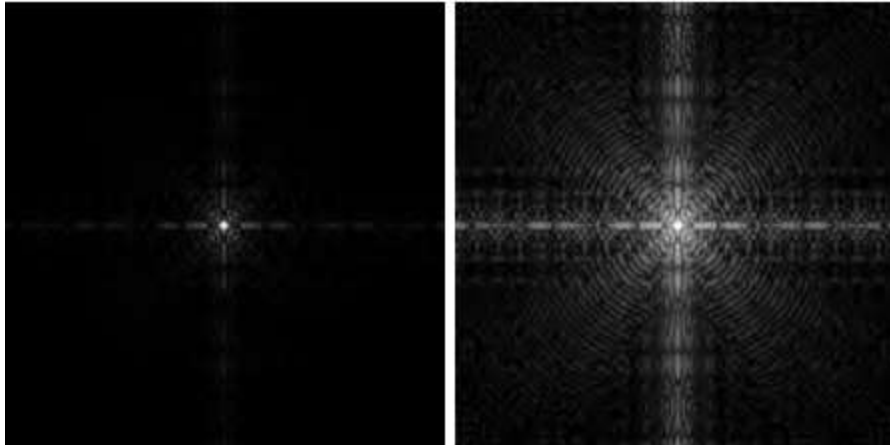
Note:

- s,r: denote the gray level of the input pixel and the output pixel.
- 'c' is a constant; to map from [0,255] to [0,255],

$$c = 255/\text{LOG}(256)$$

- the base of a common logarithm is 10

In the log transformation, the low-intensity values are mapped into higher intensity values. It maps a narrow range of low gray levels to a much wider range. Generally speaking, the log transformation works the best for dark images.



b) Inverse Log Transform

The inverse log transform is opposite to log transform. It maps a narrow range of high gray levels to a much wider range. The inverse log transform expands the values of light-level pixels while compressing the darker-level values. $s = \text{power}(10, r * c) - 1$

Note:

- s,r: denote the gray level of the input pixel and the output pixel.
- 'c' is a constant; to map from [0,255] to [0,255], $c = \text{LOG}(256)/255$

Power-Law (Gamma) Transformation

The gamma transform, also known as exponential transformation or power transformation, is a commonly used grayscale non-linear

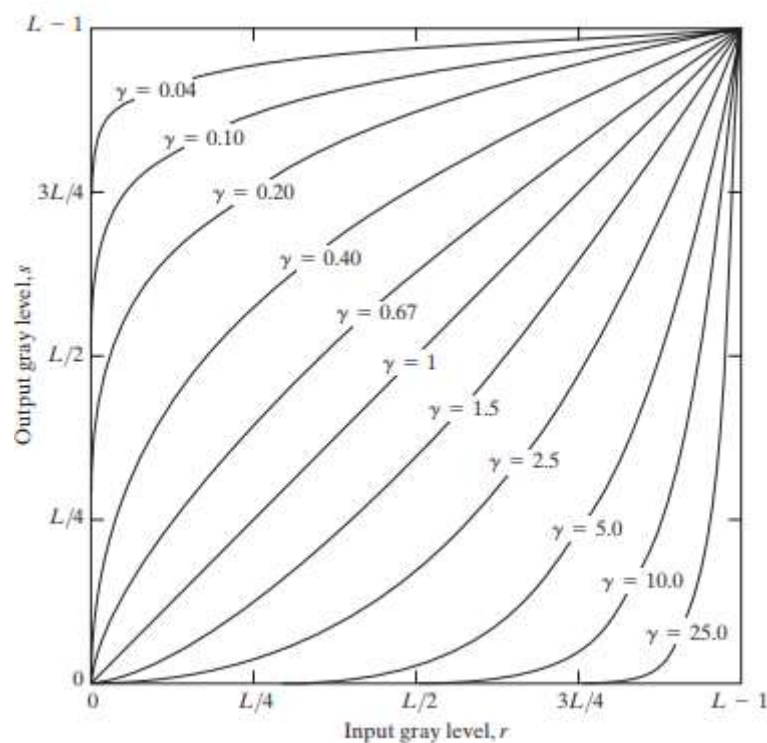
transformation. The mathematical expression of the gamma transformation is as follows:

$$s = c * \text{power}(r, \gamma), \text{ where}$$

- s, r : denote the gray level of the input pixel and the output pixel;
- ' c ' is a constant
- ' γ ' is also a constant and is the gamma coefficient.

Plots of the equation [formula] for various values of γ ($c = 1$ in all cases)

All curves were scaled to fit in the range shown. X-axis represents input intensity level ' r ', and y-axis represents the output intensity level ' s '.

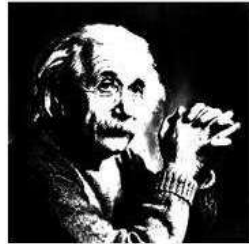


When performing the conversion, it is a common practice to first convert the intensity level from the range of 0 to 255 to 0 to 1. Then perform the gamma conversion and at last restore to the original range.

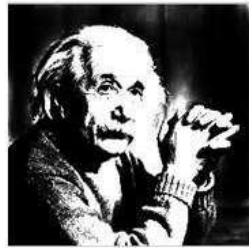
Comparing to log transformation, gamma transformation can generate a family of possible transformation curves by varying the gamma value.

Here are the enhanced images output by using different γ (gamma) values.

Gamma = 10



Gamma = 8



Gamma = 6



The gamma transformation can selectively enhance the contrast of the dark region or the light region depending on the value of γ .

- When $\gamma > 1$, the contrast of the light gray area is enhanced. Take $\gamma = 25$ for example, the pixels with the range of 0.8–1 (at the scale of 256, it corresponds to 240–255) are mapped to the range of 0–1
- When $\gamma < 1$, the contrast of the dark gray area is enhanced
- When $\gamma = 1$, this transformation is linear, that is, the original image is not changed.