.

Intensity transformations

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Methods for Image Processing

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Spatial domain

- The *spatial domain* of an image is the plane that contains the image pixels.
- The techniques that operates on the spatial domain make direct use of the information contained into the matricial representation of the image;
  - in contrast to other techniques that operate onto representation of the image in other domains (which is computed through a suitable transform).
- This kind of techniques can be formalized as: $g(x, y) = T[f(x, y)]$
- Generally, spatial domain techniques are less computationally demanding.

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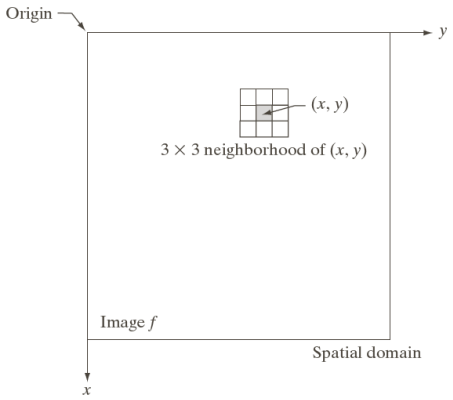
Transformations in the spatial domain



- The operator, T, is usually defined on a suitable neighborhood of (x, y).
  - A rectangular neighborhood is usually preferred.
  - When the neighborhood fall outside the image, some extending criteria have to be used
    - background-padding
    - zero-padding
    - symmetry
- If the radius of the neighborhood is 0, the transformation involves only the considered pixel and depends (only) by its intensity:
  - $s = T(r)$
  - intensity transformation or gray-level mapping.

Intensity transformations

- Intensity transformation techniques are also called *point-processing*, as opposed to the *neighborhood processing* techniques.
- Simple to implement (algorithm, table map).
- They are used to enhance images that are devoted to visual processing:
  - no general rule for stating the optimality;
  - application-dependent;
  - user-dependent.

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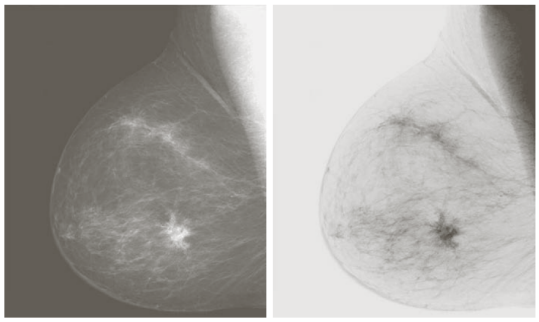
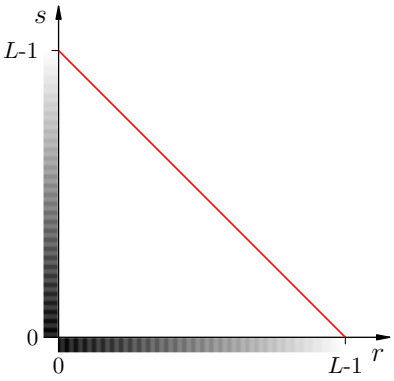
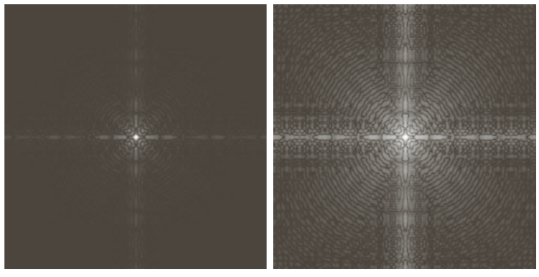
Image negative

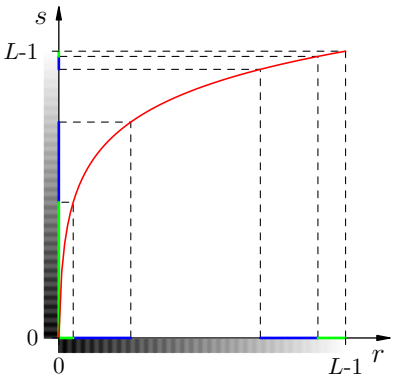




- Sometimes, the details are more detectable when the pixels intensity is reversed.
  - For instance, when the details are white or light gray and the background is dark and covers the most of the image.
- $s = L - 1 - r$

Logarithmic transformations





- $s = c\ \log(1 + r), \quad c = \frac{L-1}{\log L}$
- Useful for representing bidimensional functions that are defined on large intervals and have high and small peaks.
  - e.g.: $f : [0, 1]^2 \rightarrow [0, 10^6]$

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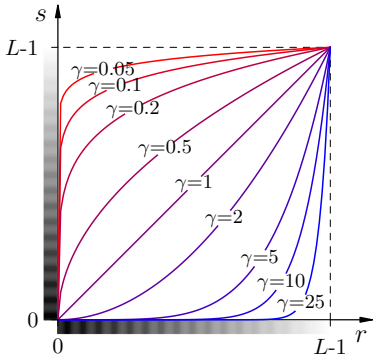
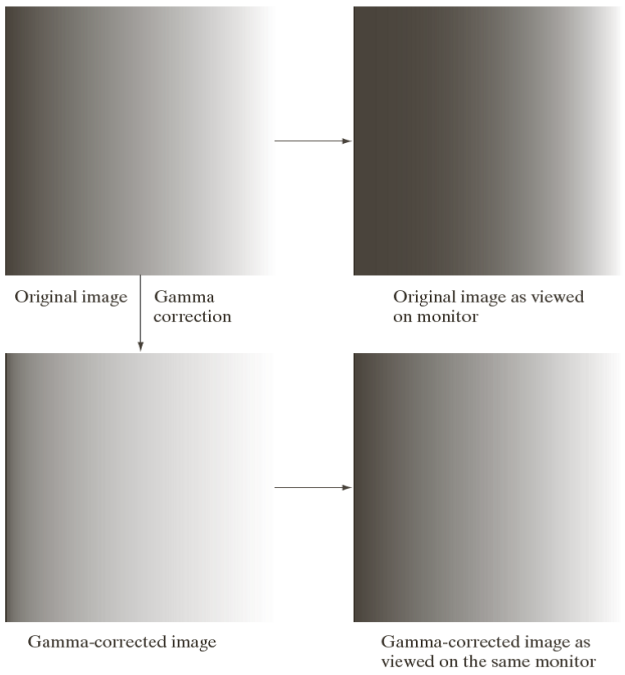
Gamma transformations

- Also called *power-law* transformations.
- $s = c\, r^{\gamma}$ (sometimes $s = c\,(r+\epsilon)^{\gamma}$)
- Used for correcting the visualization devices output.
- Useful for contrast correction (or enhancement).
- A too large or too small value for γ can compromise the results.



- $\gamma = 1$, identity
- $\gamma < 1$, lightening
- $\gamma > 1$, darkening

Gamma transformations (2)



If the gamma correction factor of the average visualization device is known in advance, a suitable correction can applied to the image intensity before the visualization.

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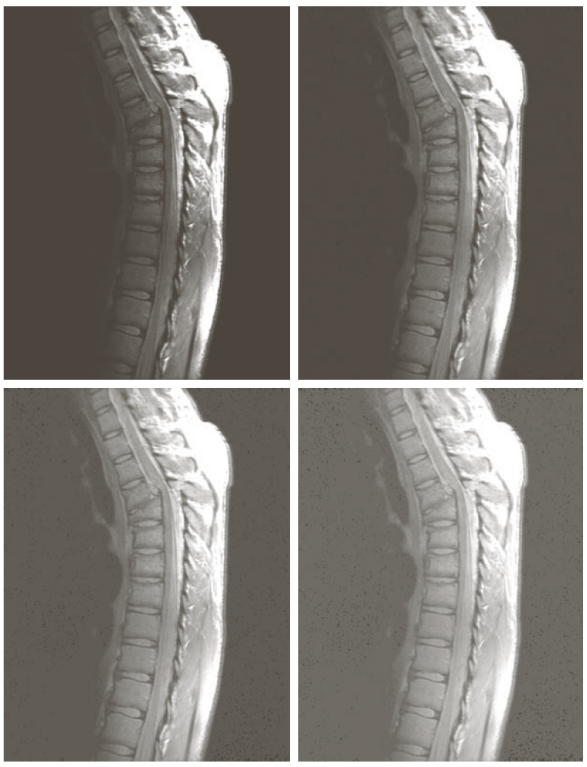
Gamma transformations (3)



a	b
c	d

(a) Original image.

Gamma transformed images with
$c = 1$, $\gamma = 0.6$ (b),
$c = 1$, $\gamma = 0.4$ (c),
and $c = 1$, $\gamma = 0.3$ (d).

Which is the best?

Gamma transformations (4)

a	b
c	d

Gamma correction can be applied also for darkening images.

(a) Original image.

Gamma transformed images with
$c = 1$, $\gamma = 3.0$ (b),
$c = 1$, $\gamma = 4.0$ (c),
and $c = 1$, $\gamma = 5.0$ (d).

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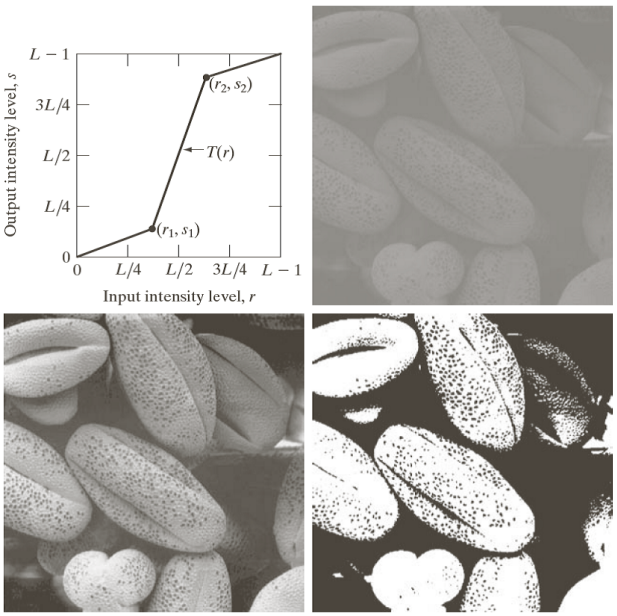
Contrast stretching transformations



a | b
c | d

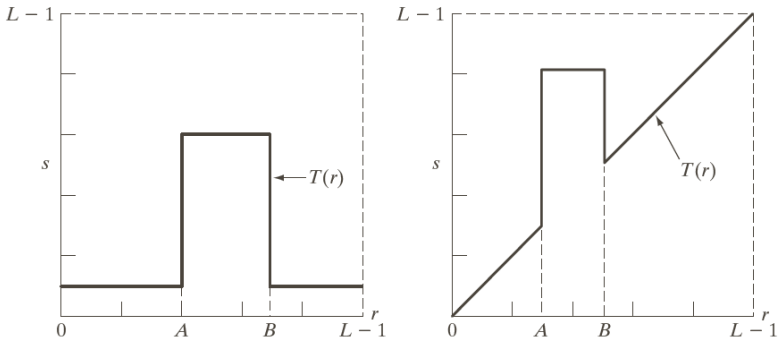
(a) General shape of the contrast stretching transformations.
(b) Low-contrast image.
(c) A processed image.

$$(r_1, s_1) = (r_{\min}, 0)$$
$$(r_2, s_2) = (r_{\max}, L-1)$$

(d) Thresholding can be view as the limit of the contrast stretching.

$$(r_1, s_1) = (r_{\text{thr}}, 0)$$
$$(r_2, s_2) = (r_{\text{thr}}, L-1)$$

Intensity level slicing transformations



a | b

- Intensity level slicing transformations highlight an intensity range.
- The transformation in (a) sets all the intensities that are not in $[A, B]$ to a low value.
- The transformation in (b) preserves the intensities that are not in $[A, B]$.

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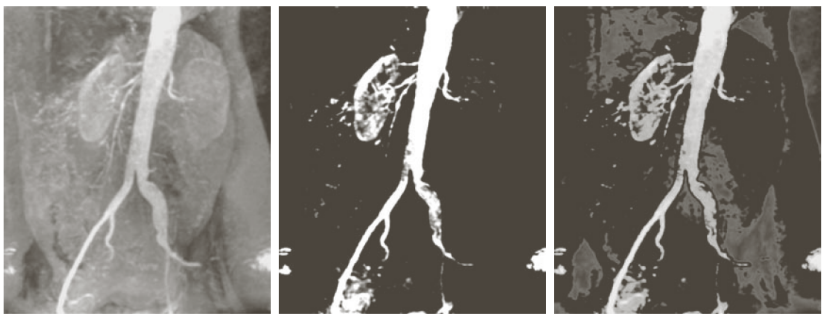
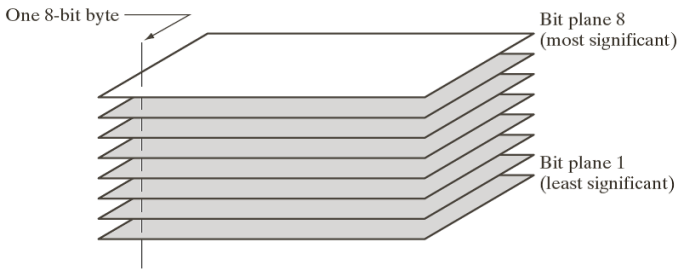
Intensity level slicing transformations (2)



a | b | c

- (a) Original image.
- (b) Vessels are highlighted by setting to $L-1$ the intensity levels that are in the range of interest and to 0 all the others.
- (c) Vessels intensities are conserved, while the others are darkened.

Bit-plane transformation



- Instead of considering it as a matrix of integer, the image can be seen as composed of layers of bits.

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Bit-plane transformation (2)

- Each layer contributes to the final appearance of the image, but most of the information is in the higher layers.

Bit-plane transformation (3)

a
b
c

Images obtained using:

- (a) bitplanes 8 and 7;
- (b) bitplanes 8, 7, and 6;
- (c) bitplanes 8, 7, 6, and 5.

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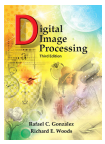
Homeworks and suggested readings



DIP, Sections 3.1, 3.2

- pp. 105–119

GIMP

- Colors
  - Brightness-Contrast
  - Threshold
  - Levels
  - Curves
  - Invert
  - Auto
    - Stretch Contrast
    - Normalize