.

Intensity transformations

Stefano Ferrari

Università degli Studi di Milano
stefano.ferrari@unimi.it

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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.

Transformations in the spatial domain

Origin

3×3 neighborhood of (x, y)

Image f

Spatial domain
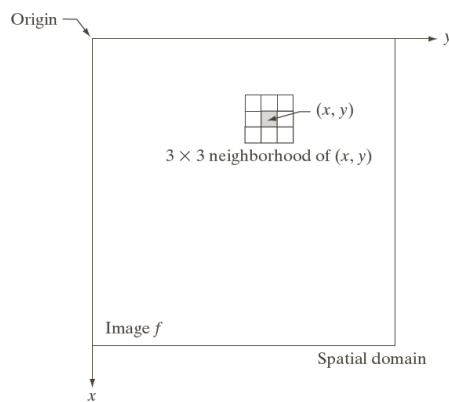
- ▶ The operator, T, is usually defined on a suitable neighborhood of (x, y).
  - ▶ A rectangular neighborhood is usually preferred.
  - ▶ When the neighborhood fall outside the image, some extending criteria have to be used
    - ▶ background-padding
    - ▶ zero-padding
    - ▶ symmetry
- ▶ If the 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.
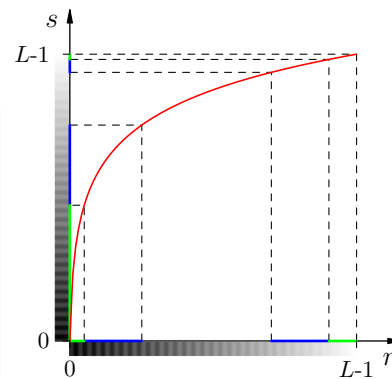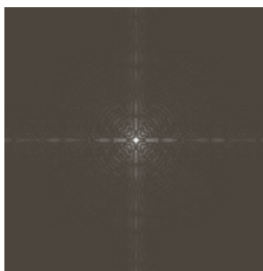
Intensity transformations

- ▶ 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.

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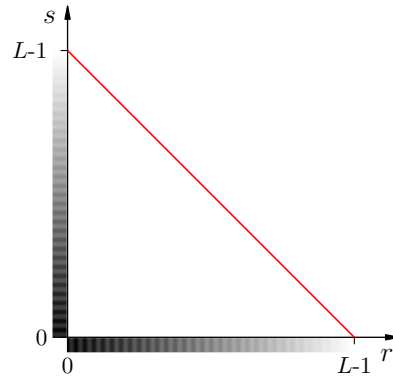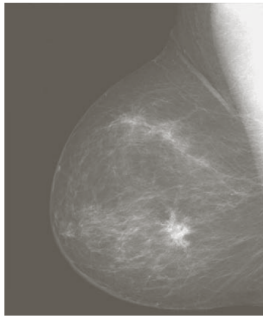
- ▶ Sometimes, the details are more detectable when the pixels intensity is reversed.
  - ▶ For instance, when the details are white or light gray and the background is dark and covers the most of the image.
- ▶ $s = L - 1 - r$

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.
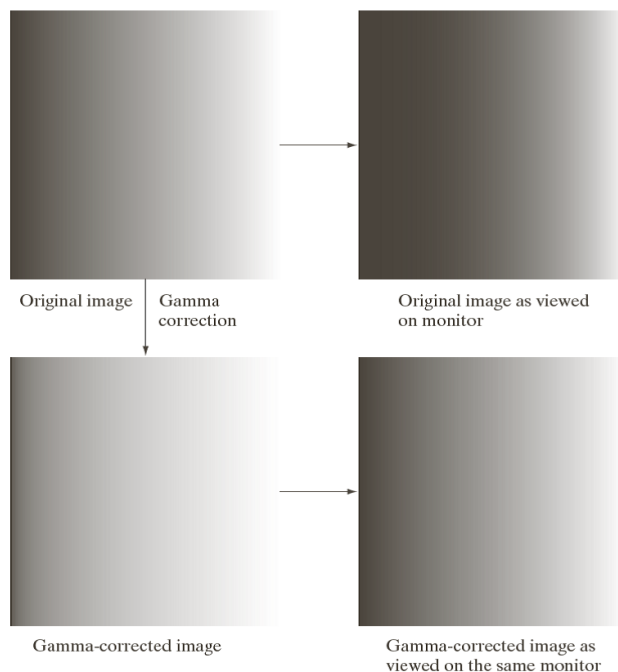 - ▶ e.g.: $f : [0, 1]^2 \to [0, 10^6]$

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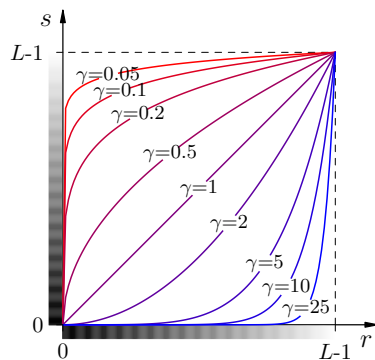
- ▶ $\gamma = 1$, identity
- ▶ $\gamma < 1$, lightening
- ▶ $\gamma > 1$, darkening

Gamma transformations (2)

Original image | Gamma correction

Original image as viewed on monitor

Gamma-corrected image

Gamma-corrected image as viewed on the same monitor

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.

Gamma transformations (3)
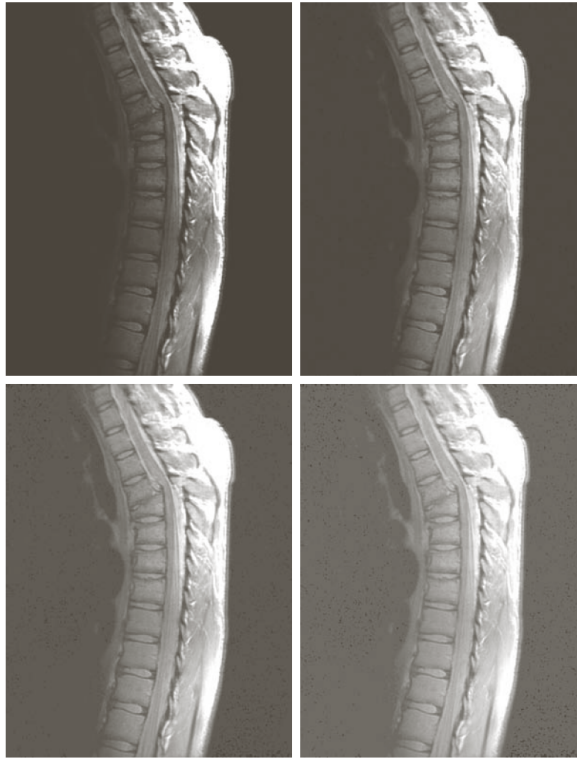
a	b
c	d

(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.
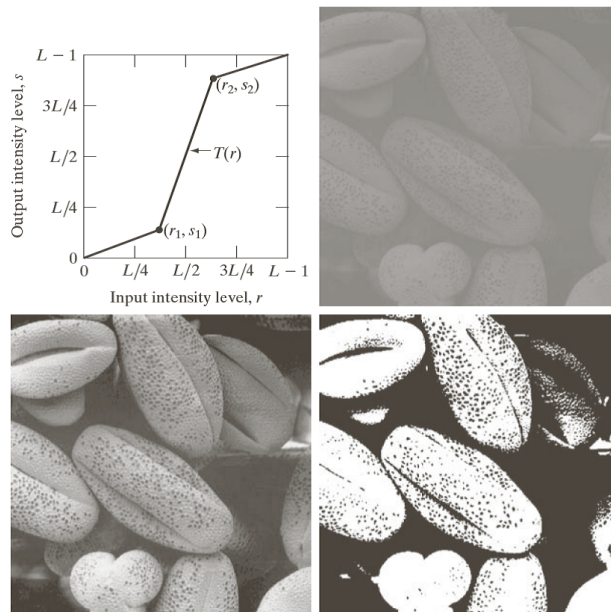
(a) Original image.

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

Contrast stretching transformations

a	b
c	d

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

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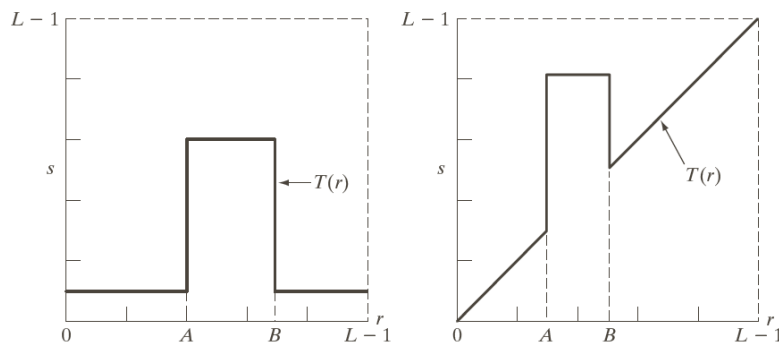$$(r_2, s_2) = (r_{max}, L - 1)$$

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

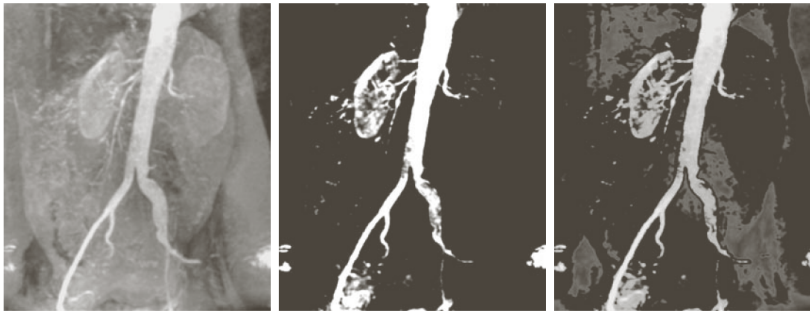$$(r_1, s_1) = (r_{thr}, 0)$$
$$(r_2, s_2) = (r_{thr}, L - 1)$$

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 $[A, B]$.

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

One 8-bit byte

Bit plane 8 (most significant)

Bit plane 1 (least significant)
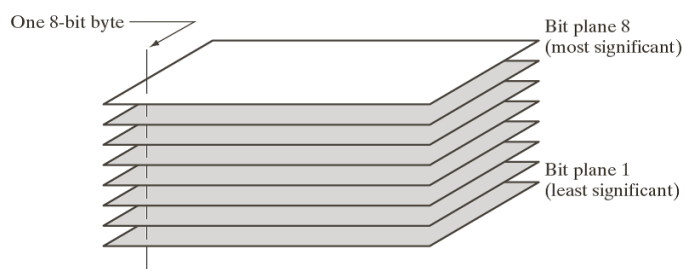
- ▶ Instead of considering it as a matrix of integer, the image can be seen as composed of layers of bits.

Bit-plane transformation (2)

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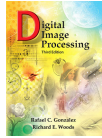

Bit-plane transformation (3)

$$\frac{\frac{a}{b}}{c}$$

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